THE

GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE V. VOL. II.

No. IX.—SEPTEMBER, 1905.

ORIGINAL ARTICLES.

I.—Eminent Living Geologists:
John Wesley Judd, C.B., LL.D., F.R.S., F.G.S.

(WITH A PORTRAIT, PLATE XXI.)

JOHN WESLEY JUDD was born at Portsmouth February 18th, 1840. His father belonged to a branch of an old Kentish family that had been settled for several generations in the Isle of Wight. His mother was the daughter of a Scotchman who had "come South" from the ancient kingdom of Fife. The Christian name given to the subject of this sketch was the result of an attempt on the part of his parents to find a compromise between the two national religions in which they had been respectively brought up.

As a boy Judd showed a strong predilection for the study of science. His interest was first directed to astronomy, and having made a telescope with cardboard tubes for himself, he spent many of the night hours in observing celestial objects; this pursuit led him to devote much of his time to mathematical studies. At a later date, however, geology began to attract his attention, and the reading of Lyell's "Principles of Geology" appears to have determined his devotion to that science.

When only 4 years old the lad lost his mother, and before he reached the age of 8 his father removed to London, having received an appointment at Somerset House. The boy's school life, which had commenced at Portsmouth, was continued at Camberwell, and when the time for leaving school arrived his fondness for study led him to adopt the teaching profession. In 1858 he entered a training college at Westminster, but in the following year an opportunity seemed to present itself for taking up more purely scientific work than lies in the way of an elementary teacher. The newly-formed Department of Science and Art instituted in 1859 an experiment in the direction of securing teachers of science by awarding certificates as the result of examination. Judd entered for these examinations in the subjects of geology and mineralogy, and obtained first-class certificates entitling him to teach these sciences. Unfortunately, however, the demand at that time for scientific instruction was too

limited to justify the enterprise on the part of the Science and Art Department, and it was soon abandoned. Judd, after some futile attempts to obtain employment as a teacher of science, resigned himself to the work of general elementary teaching and became master of a school at Horncastle in Lincolnshire. Here, however, he spent all his spare time in scientific studies, devoting the greater part of his nights to work in a small chemical laboratory which he had fitted up in his house. His holidays during three years' residence in Lincolnshire were spent in rambling about the county and making himself acquainted with its geological features.

Although the examination for the teachership in science led to no direct practical result, yet it proved the turning-point in Judd's career by introducing him to the notice of the two examiners—his subsequent friends and colleagues, Professor (afterwards Sir Andrew) Ramsay and Mr. (afterwards Sir Warington) Smyth. These geologists, after the perusal of the young candidate's papers, both communicated with him, giving him warm encouragement and offering their assistance if he came to the Royal School of Mines to continue his studies.

It was not, however, till the beginning of 1863 that Judd found himself able to accept the invitation. He then entered the Jermyn Street School by passing the examinations of the first two years with the object of taking the courses of the third year. It was, however, possible at that time to attend all the series of lectures during one year, and very gladly he availed himself of the opportunity of listening to the discourses of Hofmann, Tyndall, Huxley, Ramsay, Smyth, Percy, and Willis, as well as to occasional lectures by Owen, Jukes, and others. At the end of the third year Judd, instead of sitting for the Associateship, became a candidate for one of the newly instituted Royal Exhibitions. This he did in the hope of being able to spend three years in higher studies and research. But on winning the exhibition he found that no arrangements could be made, within the circumscribed limits of the Jermyn Street building, for such advanced work, and he somewhat reluctantly accepted an offer to become analytical chemist in the iron and steel works of Messrs. Cammell & Co. at Sheffield.

The residence of Judd at Sheffield, though limited to less than a year, exercised a very important influence upon his future career, for it was there that he formed the acquaintanceship of Henry Clifton Sorby, who became his lifelong friend. Mr. Sorby taught him to make thin sections of rocks, and fully impressed upon him the value of this method of research. This was in the year 1864—a period when the microscopic study of rocks had attracted but little attention either in this country or abroad. The residence at Sheffield was brought to a sudden end by a railway accident in which Judd nearly lost his life.

After many months of confinement to a sick bed, Judd was ordered by the doctors to abstain from settled employment for some years, and he gladly availed himself of the opportunity to return to Lincolnshire and devote an out-of-door life to continuing the

geological studies of the county which he had already commenced. The result of these labours was seen in two noteworthy additions to geological knowledge. In the first place, he was able to show that the strata which form the base of the Lincolnshire Wolds—which had been vaguely referred either to the Jurassic or the Lower Greensand—are really representatives of the Neocomian of the Continent, and an examination of the Speeton Clay of Yorkshire proved that all the zones shown to exist in Lincolnshire are present there also under different mineral conditions. In the second place, a study of the fossils in the great belt of oolitic limestones running north and south through the county of Lincoln, and continued southwards into the Midlands and northward into the East Riding of Yorkshire, demonstrated that these rocks are of *Inferior* Oolite age, and not Great Oolite, as had hitherto been supposed. His work in Lincolnshire was varied by trips to the Continent, where, with knapsack on back, he visited and studied the various equivalents of the Lincolnshire strata.

Among those who were specially interested in the results of this work was the amiable Oxford professor, John Phillips. Phillips made the suggestion that Judd should complete a geological map and memoir on Lincolnshire, as he had himself done for Yorkshire. But, on the other hand, Professor Ramsay urged Judd to accept a temporary post on the Geological Survey, promising him the opportunity of surveying the districts south of Lincolnshire, where his previous experience would be of special use. He accordingly joined the Survey in 1867, and for four years was engaged in the survey of Rutland and parts of the adjoining counties. The result of this work was to demonstrate the necessity of a revision of the whole of the Lower Oolites of the Midland districts as far south as Oxfordshire and Gloucestershire. Over the whole of this area the rocks hitherto mapped as Great Oolite were re-mapped as "Lincolnshire Limestone" and "Northampton Sand," and placed in the Inferior Oolite, while the limits and divisions of the true Great Oolite were defined. During this period Judd was able to apply the methods which had been taught him by Sorby to the investigation of the nature and origin of the ferruginous rocks of the Northampton Sand. His paper on the subject, containing a full discussion of the microscopical and chemical characters of the rocks, was read before the Geological Society in March, 1869, but was withdrawn in consequence of a new regulation being made that such papers must appear in the Survey Memoirs. It was at last published, but without figures, in 1875.

A former colleague and fellow-worker on the Geological Survey for many years writes of his work as follows:—

"Professor Judd joined the staff of the Geological Survey in 1867, and was occupied during three years in the county of Rutland and bordering portions of Leicestershire, Lincolnshire, and Northamptonshire, that are included in Sheet 64 of the old series map.

"In the course of his investigations he proved beyond question that the important group of limestones which form 'the cliff' of

Lincolnshire belong to the Inferior Oolite, and not to the Great Oolite as had been generally believed. Much confusion had arisen through the correlation of the Collyweston Slate with the Stonesfield Slate. These and other matters connected with the stratigraphy of the Lower Oolites, and especially with the age and relations of the Northampton Sands, were clearly expounded by Professor Judd. The acceptance of his views necessitated the revision of some of the previously published maps of the Geological Survey, and during the last year (1870–71) he was occupied on the Geological Survey he carried his revisions as far as he was able from the neighbourhood of Northampton into parts of Oxfordshire; but much yet remains to be done in the area near Chipping Norton.

"The description of Sheet 64 was written by Professor Judd in the memoir on 'The Geology of Rutland,' etc., issued in 1875 by the Geological Survey. This memoir contained an important Introductory Essay, 'On the Classification of the Jurassic Strata of the Midland District, and their Correlation with those of the Cotteswold Hills and the North-East of Yorkshire respectively.' In this essay, as pointed out, some of the views had been foreshadowed in previous writings by Brodie, Lycett, and to a certain extent by Morris, while Samuel Sharp of Northampton and Thomas Beesley of Banbury had concurrently been working on the Lower Oolites in their respective districts, and had been 'independently led to similar conclusions' with regard to the Lincolnshire Oolite and Northampton Sand. Nevertheless, the whole subject was dealt with by Professor Judd in a masterly way, and his original observations not only placed the subject on a sound basis but formed the guide to all subsequent workers in the Midland area."

The special work for which Judd had joined the Survey having been completed, he accepted an offer from his friend Mr. Matthew Arnold, in 1871, to join the Education Department for a time, and to act with him as an Inspector of Returns under the Education Act of 1870. For over a twelvemonth he was engaged in inspecting elementary schools and training colleges in the London area between Westminster and Edmonton. Geology was not, however, entirely neglected during this period, for he had undertaken to furnish the Geological Survey with a memoir on the districts he had surveyed in Rutland, etc., with an essay on the classification of the Lower Jurassic Strata of the Midland district. This work was published in 1875. At this period, too, he was led to pay a considerable amount of attention to the question of the age of the Wealden formation and its relations to the strata above and below it, the Jurassic and Neocomian.

Released from the work of school inspection, Judd returned with zest to geological pursuits. The patches of Jurassic strata in the north-east of Scotland attracted his attention, and, after two years of hard work in the district, he was able to show that these patches of Mesozoic strata owe their preservation to the action of great faults, by which they had been let down among the older and harder rocks. He also, with the aid of Dr. Joass and Dr. Gordon, collected

the fossils of the various beds, and showed the exact age and relations of the whole series from the Trias to the Upper Oolites.

The study of the Mesozoic strata of the east coast of Scotland naturally led to the examination of the equivalent beds in the western coasts and islands, and here Judd, in addition to working out minutely the succession of Jurassic and Triassic rocks, was able to show that interesting representatives of the Carboniferous and Cretaceous systems—the presence of which had been hitherto quite unsuspected—actually occur in these Western Highlands.

The preservation of patches of younger rocks in the west of Scotland, while as in the eastern area partly due to the action of great faults, is to a still greater extent the result of the protection afforded by the vast masses of igneous rocks with which they are associated. Judd's attention was therefore soon directed to the unravelling of the complexities of these rock-masses, and of their relations to the Mesozoic strata. The task was at the time one of great difficulty, for no Ordnance Maps of the district had been published, while the facilities for travelling in the district, especially to a man of small means, were far less than even at the present day.

Macculloch had demonstrated that these igneous rocks are of later date than all the Secondary strata with which they are so closely associated, while Zirkel had proved that among the rocks of Skye true granites and gabbros occur. Other writers, however, had maintained the Jurassic age and a metamorphic origin for these rocks. The result of Judd's work was to establish the fact that between the most perfect granites and gabbros there exists every gradation, to rhyolites and pitchstones on the one hand, and to basalts and tachylytes on the other hand; and thus that the distinction between 'plutonic' and 'volcanic' rocks is a purely artificial one. That all these igneous rocks must be of Tertiary age he proved by showing that they overlie and are intrusive in the youngest Cretaceous strata (Chalk of the Zone of *Belemnitella mucronata*).

As the result of a general survey of the igneous rock-masses, he was able to state that they indicate the existence of five centres of eruptive activity—the sites of great Tertiary volcanoes; and that concerning the dimensions and history of these volcanoes important evidence can be obtained; the extinction of these great volcanoes was shown to have been followed by sporadic outbursts all over the area. He maintained that the general order of succession in the eruption of the igneous materials was from the acid to the more basic varieties.

The results of this work in the Western Isles of Scotland attracted much interest among geologists, and the veterans of the science—Lyell, Darwin, and Scrope—were warm in their praise and kindly in their encouragement and aid. In 1874 Sir Charles Lyell, then nearly blind, invited Judd to spend part of the Summer at his home in Forfarshire and to visit and talk over many of the scenes of the master's early labours, while helping to revise a new edition of the "Elements of Geology." After the death of Lyell,

Darwin used to invite Judd from time to time to meet him and discuss current geological topics. Scrope, at this period too old and infirm to undertake further travels, sent Judd to visit the different volcanic districts of Europe, which he himself knew so well, aiding him the while by conversation and correspondence. Never surely was young geologist so fortunate and happy in securing the friendship and teaching of men like Lyell, Darwin, and Scrope!

As the results of his travels over Europe, Judd published a series of papers under the title of "Contributions to the Study of Volcanoes." He also read before the Geological Society a paper on the ancient volcano of Schemnitz. In his earlier memoirs he had been content to adopt Bunsen's classification of rocks in an Acid and a Basic series. He now, however, showed that such a simple classification was beset with difficulties, and proposed the term "Intermediate" for that extensive class of rocks which could not be conveniently assigned to either of Bunsen's classes. The French geologists, later, adopted the same plan, calling the intermediate rocks "Neutral." At a later date Judd proposed the separation of the smaller group of "Ultrabasic rocks" as a distinct class. His study of the contemporaneous volcanic rocks of Bohemia and Hungary led to the recognition of the fact that a geographical distribution of rocks exists, not less marked than that of animals and plants, and this idea crystallized in the suggestion of the term "petrographical province," which is now so universally adopted. While travelling over the volcanic districts, Judd was able to send to his friend Professor Story Maskelyne large collections of rock-specimens, which were deposited in the Mineral Department of the British Museum.

During his journeys upon the Continent for the purpose of studying the volcanic rocks, Judd never lost sight of the importance of making himself acquainted with the best methods of teaching science. His frequent intercourse with his former teacher and constant friend—Professor Huxley—had led him to recognize the supreme value of practical teaching in science, and, while visiting the various universities and mining schools of the Continent, this point was kept constantly in view. In 1876 the opportunity of taking up the teaching of geology arrived, through the resignation by Sir Andrew Ramsay of the professorship of geology in the Royal School of Mines on his appointment to the Directorship of the Geological Survey. By the unanimous vote of the Council Judd was recommended for the vacant post, and at once entered on its duties.

After lecturing for a year at Jermyn Street, it was found that the impossibility of obtaining laboratory accommodation necessitated the removal of the geological division to South Kensington, to which place most of the other divisions of the school had already been transferred, and in 1881 the sphere of work of the school was enlarged by the creation of the Royal College of Science. Here, with the assistance of Huxley, Judd organized a system of practical teaching in geology, similar to that already established for biology,

and this system during the next twenty-five years was gradually developed with the co-operation of able students, who became his assistants, among whom may be especially mentioned Professor Cole, the late Mr. A. V. Jennings, Dr. W. F. Hume, Mr. T. H. Holland, Dr. Evans, Dr. Cullis, and Professor Skeats.

In 1878 Professor Judd married Jeannie Frances Jeyes, a niece of his old friend and fellow-worker in the geology of the Midlands —S. Sharp, Esq., F.S.A., F.G.S. In 1877 he was elected one of the Secretaries of the Geological Society, and served that office for ten years till he was elected President, during the years 1886 and 1887. He had received the Wollaston Fund in 1868, and in 1891 was awarded the Wollaston Medal.

During nearly thirty years that he has been engaged in teaching, only the Summer vacations have been available for field-work. But in these vacations the igneous rocks of the Western Isles and other parts of Scotland have been examined and the collections made subsequently studied in the laboratory. The results have been published in a series of petrographical memoirs in the Quarterly Journal of the Geological Society. Teaching the science with London as a centre, all questions concerning the geology of the London Basin were naturally of special interest to him, and thus he was led to the publication of papers on the geology of the London and Hampshire Basins and the correlation of their strata. With the aid of a pupil, the late Mr. Collett Homersham, he was able to study the materials obtained in a deep boring at Richmond, and to show that there, and also in the deep well at Meux boring in the Tottenham Court Road, richly fossiliferous deposits of Lower Oolite age occur.

One who has known Professor Judd for many years, and is competent to judge of the value of his work as a geologist, writes :—

"The breadth and accuracy of Judd's knowledge is the characteristic which from the first has most impressed me. Trained in youth as a practical chemist, well grounded at the Royal School of Mines in physics and biology, early to appreciate the importance of the microscope in the study of rocks, with his experience in the field as a worker on the staff of the Geological Survey greatly widened by study of some of the most interesting districts on the Continent, he could deal with all sides of a problem, whether petrological, or physical, or palæontological, and he contrived, notwithstanding the incessant demands of educational work in later years, to keep well up to date in the literature of the science. He has made—and this can be said of very few—valuable contributions to all departments of geology, and in proof of this I need only recall papers in the Mineralogical Magazine, such as that on Scapolite, those in this periodical on glacial questions and on volcanoes, afterwards developed into his well-known book, those, chiefly in the Quarterly Journal, in which he dispelled the fog which obscured our Neocomian deposits, his memoir on the geology of Rutland, and the papers on the west coast of Scotland, which, whether the verdict on one point be ultimately for or against him, will always rank as classic.

In fact, whatever work he has done, whether scientific, educational, or administrative, has always been characterized by a careful observation, a conscientious thoroughness, and an earnest desire to arrive at the truth."

When Professor Huxley retired from his professorship in the Royal College of Science in 1885, he retained the post of Honorary Dean, but many of the duties of the office were undertaken by Professor Judd, who on the death of Huxley in 1895 was made Dean and created a C.B. He was elected a Fellow of the Royal Society in 1877, and has served twice for periods of two years each on the Council, acting as a Vice-President of the Society in 1902 and 1903. In 1887 he was President of the Geological Section of the British Association at the Aberdeen meeting, and some years subsequently had the honorary degree of LL.D. conferred upon him by the University of that city. He has acted for a considerable time as Chairman of the Seismological Committees both of the British Association and the Royal Society, and is Foreign Secretary of the Mineralogical Society.

While educational, official, and other duties have necessarily limited his opportunities for research during recent years, he has found time for study of materials obtained by boring in the Nile Delta, for work upon the products of the great eruption at Krakatoa, on the rocks brought home from the Ruby district of Burma by Mr. C. Barrington Brown, and especially on the cores and other specimens obtained in the boring in the Coral-reef of Funafuti. Various incidental questions like those of the nature of Sarsens, the materials employed in the building of Stonehenge, the nature of the rocks forming Rockall, with problems arising out of the study of rock-forming minerals, have engaged his attention and formed the subject of numerous papers. Of larger works for students he has written a revised edition of Lyell's Elements under the name of "The Student's Lyell"; "Volcanoes: What they are and what they Teach"; a translation, with introductory notice, of Behren's "Microchemical Analysis"; and critical introductions to Darwin's geological books, one of these having been translated into French by his old friend Professor Renard.

From the teaching work, which has occupied so much of his time and energies during nearly thirty years, Mr. Judd has now just retired, having reached the age limit. Many hundreds of his students now occupy important teaching posts or are engaged in the geological surveys of our own country, the Colonies, India, and Egypt, while still more are engaged in mining and metallurgical work in all parts of the globe.

One of his old Assistants who knows his methods of teaching, and has gone through the work of the Royal College of Science with him, writes:—

"As a teacher of geology Professor Judd holds a position of the highest distinction. The courses of instruction designed and gradually evolved by him have long been regarded as among the most perfect and complete of their kind. He was one of the very

first to introduce into the academic curriculum systematic practical instruction in the subject, and of the many excellent courses in geology now open to students in various parts of the world, not a few are based, wholly or in part, upon the methods originated by him and carried out so ably and for so many years in the Royal College of Science.

"Throughout his career as a teacher of science Professor Judd has been an enthusiastic advocate of the system employed in the Royal College of Science of enabling the student to concentrate his whole attention upon one subject at a time, instead of requiring him to study several different and not necessarily cognate subjects simultaneously. He has also strongly upheld the principle of making practical teaching in the laboratory strictly sequential to, and directly illustrative of, the lectures. In his own department, whenever possible, the laboratory work has been arranged as an immediate extension of the lectures, in which the student has had an opportunity of examining systematically and illustrating experimentally such data and principles of the subject as are capable of exemplification in this manner; and it is doubtless to this excellent system of simultaneous theoretical and practical work that the very real knowledge of their subject which has characterized such a large proportion of his pupils has been mainly due. Another feature which has determined the success of Prof. Judd's teaching is his freedom from conservativism: if the advances made in his subject or in any branch of it have pointed to the desirability of changes in the method of its presentation to the student, he has never shrunk from the abandonment of methods already adopted or from such wholesale reconstruction of his courses as may have seemed necessary to bring them into touch with the most recent views.

"The relations between Professor Judd and his students have always been of the pleasantest and most cordial kind. He has invariably taken a keen personal interest in all who have come under his charge, and has always been ready to help and advise them, not only in their geological studies, but also in all matters connected with their college life and their future career. He was constantly invited to act as an officer of the many clubs and societies of the college, and in such a capacity always set an excellent example to those associated with him by the very conscientious manner in which he performed the duties which his acceptance of office entailed, notwithstanding his very heavy duties as Professor and Dean. These and many other traits endeared him to the students, among whom he was very popular, and by whom he was regarded with great respect and esteem. It must be a constant source of pleasure to him to feel that the many hundreds of students who have passed through his hands, and who are now distributed all over the world, will always entertain the pleasantest recollections of their association with him; they will learn with regret that he has relinquished the post which he has filled so long and honourably."

LIST OF SCIENTIFIC PAPERS AND BOOKS BY PROFESSOR JOHN W. JUDD.

1867. "On the Strata which form the base of the Lincolnshire Wolds": Quart. Journ. Geol. Soc., vol. xxiii, pp. 227–251.

1868. "On the Speeton Clay": Quart. Journ. Geol. Soc., vol. xxxiv, pp. 218–250.

1869. "On the Origin of the Northampton Sand." This paper was read at the Geological Society on March 10th, 1869, and an abstract of it appeared in the Phil. Mag., vol. xxxviii, pp. 400–401. Its publication was undertaken by the Geological Survey, but was delayed till 1875, when it appeared as chapter vi of the "Geology of Rutland," pp. 113–138, but without illustrations.

1870. "Additional Observations on the Neocomian Strata of Yorkshire and Lincolnshire, with notes on their Relations to beds of the same age throughout Northern Europe": Quart. Journ. Geol. Soc., vol. xxvi, pp. 326–347.

1870. "On the use of the term Neocomian": Geol. Mag., Vol. VII, pp. 220–227.

1870. "On the Age of the Wealden": Brit. Assoc. Rep., xl (sect.), p. 77.

1871. "On the Puntield Formation": Quart. Journ. Geol. Soc., vol. xxvii, pp. 207–227.

1871. "On the Anomalous Mode of Growth of certain Fossil Oysters": Geol. Mag., Vol. VIII, pp. 355–359.

1873. "The Secondary Rocks of Scotland," First Paper.—Strata of the East Coast: Quart. Journ. Geol. Soc., vol. xxix, pp. 97–195.

1874. "The Secondary Rocks of Scotland," Second Paper.—On the Ancient Volcanoes of the Highlands and the Relations of their Products to the Mesozoic Strata: Quart. Journ. Geol. Soc., vol. xxx, pp. 220–302.

1875. "On the Structure and Age of Arthur's Seat, Edinburgh": Quart. Journ. Geol. Soc., vol. xxxi, pp. 131–148.

1875. "Contributions to the Study of Volcanoes."—Introduction; The Lipari Islands: Geol. Mag., Dec. II, Vol. II, pp. 1–16, 56–70.

1875. "Contributions to the Study of Volcanoes."—Vulcano: ibid., pp. 99–115.

1875. "Contributions to the Study of Volcanoes."—Stromboli: ibid., pp. 145–152, 206–214.

1875. "Contributions to the Study of Volcanoes."—The Island of Ischia: ibid., pp. 245–257.

1875. "Contributions to the Study of Volcanoes."—The Ponza Islands: ibid., pp. 298–307.

1875. "Contributions to the Study of Volcanoes."—The Great Crater-lakes of Central Italy: ibid., pp. 348–356.

1875. Instructions on Volcanoes: Arctic Manual published by Admiralty.

1875. "The Geology of Rutland, and parts of Lincoln, Leicester, Northampton, Huntingdon, and Cambridge (Sheet 64 of the 1 inch Geological Map), with an Introductory Essay on the Classification and Correlation of the Jurassic Rocks of the Midland District of England": Memoirs of the Geological Survey of England and Wales, pp. xvi–320, with 11 plates and 19 woodcuts.

1876. "Contributions to the Study of Volcanoes."—On the Origin of Lake Balaton in Hungary: Geol. Mag., Dec. II, Vol. III, pp. 5–15.

1876. Review of "Bořicky's Memoirs on the Basalts and Phonolites of Bohemia": ibid., pp. 35–38.

1876. "Method of Determining the Species of Felspars in Rocks," being an account of Szabo's Flame-reactions.—Science Conferences held in connexion with the Loan Collection of Scientific Apparatus: Vol. on Chemistry, Biology, Geology, etc., pp. 418–419.

1876. "On the Origin of Lakes," a reply to criticism: Geol. Mag., Dec. II, Vol. III, pp. 187–189.

1876. "Contributions to the Study of Volcanoes," Second Series.—The Ancient Volcanoes of Europe: ibid., pp. 53–63.

1876. "Contributions to the Study of Volcanoes," Second Series.—On the Volcanic Outbursts which preceded the Formation of the Alpine System: ibid., pp. 200–215.

1876. "Contributions to the Study of Volcanoes," Second Series.—On the Interval which separated the two great Periods of Volcanic Activity in Connexion with the Formation of the Alpine System: ibid., pp. 337–345.

1876. "Contributions to the Study of Volcanoes," Second Series.—On the Volcanic Outbursts which accompanied and followed the Formation of the Alpine System: ibid., pp. 529–538.

1876. "Formation of Rock-Basins": ibid., pp. 523–525.

1876. "On the Ancient Volcano of the district of Schemnitz, Hungary": Quart. Journ. Geol. Soc., vol. xxxii, pp. 292–325.

1877. Opening Lecture at the Royal School of Mines: Roy. Sch. of Mines Mag., vol. i, pp. 103–106.

1877. "Deep Well-borings in London": *Nature*, vol. xvi, pp. 2–3.

1878. "The Secondary Rocks of Scotland," Third Paper.—The Strata of the Western Coasts and Islands: Quart. Journ. Geol. Soc., vol. xxxiv, pp. 660–741.

1878. "A Problem for Cheshire Geologists" (being an account of the Liassic Outlier at Wem): Chester Soc. Sci., vol. iii, pp. 45–49.

1879. Notes on some of the Antiquities of the Western Coasts and Isles of Scotland contributed to the Rev. J. M. Joass, and published in the Proceedings of the Scottish Antiquarian Society.

1880. "On the Oligocene Strata of the Hampshire Basin": Quart. Journ. Geol. Soc., vol. xxxvi, pp. 660–741.

1880. "On the Classification of the Tertiary Deposits": Pop. Sci. Review, vol. xix, pp. 122–136.

1881. "On the Occurrence of the Remains of a Cetacean in the Lower Oligocene Strata of the Hampshire Basin": Quart Journ. Geol. Soc., vol. xxxvii, pp. 708–709.

1881. "Volcanoes: What they are and what they Teach": vol. xxxv of the International Scientific Series.

1882. "On the Relations of the Eocene and Oligocene Strata in the Hampshire Basin": Quart. Journ. Geol. Soc., vol. xxxviii, pp. 461–486.

1882. "Possibility of finding workable Coal-seams under the London Area": *Nature*, vol. xxv, pp. 311–313, 361.

1883. "On the Methods which have been devised for the Rapid Determination of the Specific Gravity of Rocks and Minerals": Proc. Geol. Assoc., vol. viii, pp. 278–287.

1883. (With Professor G. A. J. Cole) "On the Basalt-glass (Tachylyte) of the Western Isles of Scotland": Quart. Journ. Geol. Soc., vol. xxxix, pp. 444–464.

1884. "Krakatoa": Proceedings of Royal Institution of Great Britain, May 2nd, 1884.

1884. "On the Jurassic Deposits which underlie London" (with an Introduction by J. Collett Homersham and Appendices by Professor T. Rupert Jones, Dr. G. J. Hinde, and Mr. G. R. Vine): Quart. Journ. Geol. Soc., vol. xl, pp. 724–794.

1885. (With J. Collett Homersham) "Supplementary Notes on the deep Boring at Richmond, Surrey": Quart. Journ. Geol. Soc., vol. xli, pp. 523–528.

1885. Obituary Notice of R. A. C. Godwin-Austen: Proc. Roy. Soc., pp. ix–xiii.

1885. "Report on a Series of Specimens of the Deposits of the Nile Delta, obtained by boring operations undertaken by the Royal Society": Proc. Roy. Soc., vol. xxxix, p. 213.

1885. "On the Occurrence as a Common Rock-forming Mineral of a Remarkable Member of the Enstatite Group (Amblystegite *nov.* Rath)": Geol. Mag., Dec. III, Vol. II, pp. 173–174.

1885. "On the Tertiary and Older Peridotites of Scotland": Quart. Journ. Geol. Soc., vol. xli, pp. 354–418.

1885. Address to the Geological Section of the British Association (Aberdeen): Brit. Assoc. Rep.

1886. "On the Gabbros, Dolerites, and Basalts of Tertiary Age in Scotland and Ireland": Quart. Journ. Geol. Soc., vol. xlii, pp. 49–97.

1886. "On Marekanite and its Allies": Geol. Mag., Dec. III, Vol. III, pp. 241–248.

1886. "On the Relations between the Solution Planes of Crystals and those of Secondary Twinning, and on the Mode of Development of Negative Crystals along the former—a Contribution to the Theory of Schillerization": Min. Mag., vol. vii, pp. 81–92.
1887. "On the Discovery of Leucite in Australia": Min. Mag., vol. vii, p. 194.
1887. "On the Unmaking of Flints": Proc. Geol. Assoc., vol. x, pp. 217–226.
1887. "On Tabasheer": *Nature*, vol. xxxv, p. 488.
1887. Anniversary Address to Geological Society ("The Relations of Geology and Mineralogy"): Quart. Journ. Geol. Soc., vol. xliii, pp. 3–57.
1888. Anniversary Address to Geological Society ("The Relations of Geology and Biology"): Quart. Journ. Geol. Soc., vol. xliv, pp. 3–56.
1888. "The Eruption of Krakatoa and subsequent Phenomena," Part i.—On the Volcanic Phenomena of the Eruption and on the Nature and Distribution of the Ejected Materials: Phil. Trans., extra vol. for 1888, pp. 1–46.
1888. "The Natural History of Lavas as illustrated by the Materials ejected from Krakatoa": Brit. Assoc. Rep. (1887) and GEOL. MAG., Dec. III, Vol. V, pp. 1–11.
1888. "On the Development of a Lamellar Structure in Quartz Crystals by Mechanical Means": Min. Mag., vol. viii, pp. 1–8.
1889. "Statical and Dynamical Metamorphism": GEOL. MAG., Dec. III, Vol. VI, pp. 243–249.
1889. "The Growth of Crystals in Igneous Rocks after their Consolidation": Quart. Journ. Geol. Soc., vol. xlv, pp. 175–186.
1889. "The Tertiary Volcanoes of the Western Isles of Scotland": ibid., pp. 187–219.
1889. "On the Processes by which a Plagioclase Felspar is converted into a Scapolite": Min. Mag., vol. viii, pp. 186–201.
1890. Critical Introduction to New Edition of Charles Darwin's "Coral Reefs," "Observations on Volcanic Islands," and "South America." (The second of these was translated into French by Professor Renard in 1902.)
1890. "On the Relations between the Gliding Planes and the Solution Planes of Augite": Min. Mag., vol. ix, pp. 192–197.
1890. "The Propylites of the Western Isles of Scotland and their Relation to the Andesites and Diorites": Quart. Journ. Geol. Soc., vol. xlvi, pp. 341–385.
1890. "Chemical Changes in Rocks under Mechanical Stresses": Journ. Chem. Soc., vol. lvii, pp. 404–425.
1891. "The Rejuvenescence of Crystals": Proc. Roy. Inst. and Report of Smithsonian Institution, 1893.
1892. "Additional Note on the Lamellar Structure of Quartz Crystals, and the Methods by which it is developed": Min. Mag., vol. x, pp. 123–134.
1893. "On Inclusions of Tertiary Granite in the Gabbros of the Cuillin Hills, Skye, and on the Products resulting from the Partial Fusion of the Acid by the Basic Rock": Quart. Journ. Geol. Soc., vol. xlix, pp. 175–195.
1893. "On Composite Dykes in Arran": Quart. Journ. Geol. Soc., vol. xlix, pp. 556–565.
1894. Introductory Chapter to Behren's "Manual of Microchemical Analysis."
1894. "The Chemical Action of Marine Organisms": *Fortnightly Review*.
1895. "The Scientific Results of the 'Challenger' Expedition."—Geology, Coral Reefs: Nat. Sci., vol. vii, p. 18.
1895. "On some Massive Minerals (Simple Crystalline Rocks) from India and Australia": Min. Mag., vol. xi, p. 56.
1895. "On the Structure-Planes of Corundum": Min. Mag., vol. x, pp. 149–
1896. (With C. Barrington Brown) "The Rubies of Burma and Associated Minerals: their mode of Occurrence, Origin, and Metamorphoses."—A Contribution to the History of Corundum: Phil. Trans., vol. 187A, pp. 151–228.
1896. "The Student's Lyell" (a revised edition of Lyell's "Student's Elements of Geology").
1897. Inaugural Address at the Opening of the Session 1896–7 of the Royal College of Science and Royal School of Mines.
1897. "Second Report on a Series of Specimens of Deposits from the Nile Delta, obtained by Boring Operations undertaken by the Royal Society": Proc. Roy. Soc., vol. lxi, pp. 32–40.

1897. "William Smith's Manuscript Maps": Geol. Mag., Dec. IV, Vol. IV, pp. 439–447.
1898. "The Earliest Engraved Geological Maps of England and Wales": ibid., Dec. IV, Vol. V, pp. 97–103.
1898. "The Earliest Geological Maps of Scotland and Ireland": ibid., Dec. IV, Vol. V, pp. 145–149.
1898. Obituary Notice of John Carrick Moore: Proc. Roy. Soc., vol. lxiii, pp. xxix–xxxii.
1898. "On the Petrology of Rockall": Trans. Roy. Irish Acad., vol. xxxi, pt. 3, pp. 48–57.
1899. "Notes on Rockall Island and Bank": Geol. Mag., Dec. IV, Vol. VI, pp. 163–167.
1899. (With W. E. Hidden) "On a new Mode of Occurrence of Ruby in North Carolina": Min. Mag., vol. xii, pp. 139–149 (also in Amer. Journ. Sci., ser. iv, vol. viii, pp. 370–379).
1901. "Volcanoes and Volcanic Action": Antarctic Manual, pp. 188–192.
1901. "Note on the Structure of Sarsens": Geol. Mag., Dec. IV, Vol. VIII, pp. 1–2.
1902. "Note on the Nature and Origin of the Rock Fragments found in the Excavations made at Stonehenge by W. Gowland, Esq.": *Archæologia*, vol. lviii, pp. 106–118 (also in Wilts Arch. & Nat. Hist. Mag., vol. xxxiii, pp. 47–61, and, 1903, Geol. Mag., Dec. IV, Vol. X, p. 129).
1904. "The Atoll of Funafuti: Borings into a Coral Reef and the Results," being the Report of the Coral Reef Committee of the Royal Society: Extra vols. of Phil. Trans. Sect. x, "General Report on the Materials sent from Funafuti, and the Methods of dealing with them," pp. 167–185; Sect. xii, "The Chemical Examination of the Materials from Funafuti," pp. 362–389.
1904. Obituary Notice of Sir Clement Le Neve Foster: Proc. Roy. Soc., vol. lxxv, pt. 4, pp. 371–377 (also in Min. Mag., vol. xiv, pp. 57–59).
1904. Obituary Notice of Frank Rutley: Min. Mag., vol. xiv, pp. 59–61.

II.—The Chalk Bluffs at Trimingham.

By Professor T. G. Bonney, D.Sc., F.R.S., and Rev. E. Hill, M.A., F.G.S.

(PLATE XXII.)

THE huge masses of chalk in the glacial drift on both sides of Cromer, and especially at the headland near Trimingham, have for many years attracted the attention of geologists. In this Magazine (Dec. II, Vol. VII, 1880, p. 55) and in the Survey Memoir on the Geology of the Country around Cromer, published in 1882, Mr. Clement Reid ascribes those at the latter place to the advance of an ice-sheet by which the chalk has been thrust up into a kind of fold and the flint layers have been bent, illustrating his interpretation by a diagrammatic section. We visited the Cromer cliffs for the first time in 1892, and after a careful examination of the Trimingham headland, not only felt more strongly than before certain weak points in Mr. Reid's reasoning, but also observed some facts difficult to reconcile with his conclusions. Since that date we have more than once visited these sections, and found last April that comparatively recent inroads of the sea had made great changes which had shown the relations of the chalk and glacial drift to be, in our opinion, incompatible with Mr. Reid's interpretation.

In 1892 two separate masses or 'bluffs' of chalk, as he describes in the Memoir (p. 95), were exposed in the drift at the base

of the cliff near Trimingham. In the western of these the bands of flint were contorted, though not quite as represented in his diagram (p. 116), for the top one was again bent up on the land side. Above, and to some extent behind it, was a bed of bluish-grey boulder-clay[1] with no sign of contortion beyond its occurrence in these two positions, which here and there was parted from the chalk by a thin layer of coarse gravel. Over the clay came a bedded sand with much internal contortion, and above this a second boulder-clay (rather browner in colour and less pebbly) lying apparently even and undisturbed. The chalk bluff ended landwards on both sides in an almost vertical wall (if anything, slightly overhanging). The drift beds on the eastern side were a little more confused than on the other; the upper boulder-clay seemed slightly more laminated, and the lower one was rather thicker.

The eastern bluff was divided into two masses, one about 30 feet, the other about 50 feet long, by a V-shaped gully, about 10 feet wide, filled with laminated clay. At its ends the flint bands, so far as they could be seen, showed no contortion, nor did the drift beds above appear 'rucked up.' In fact, we saw no indication of what might have been expected if, after at least some of the glacial drift had been deposited, a great ice-sheet had, as it advanced, pushed up the chalk in a sharp fold, and the following note written at the time by one of us (T. G. B.) expresses our conclusion:—"After prolonged examination I am convinced (with Hill) that C. R. is wrong in his interpretation of the record; that there is no contortion,[2] and that the mass of chalk is a boulder."

One of us (E. H.) visited the section in the Spring of 1898 and of 1899. On the former occasion he noted on the top of the western boulder a bed of gravel, "probably débris of denuded chalk before transport," and on that of the eastern one a bedded sandy clay filling up its inequalities, and overlain by bedded sands, which were seen to rest on the chalk at its northern end. On the latter occasion he wrote: "The chalk bluff is probably much wasted. Now there is no vertical bedding on the higher cliff, only in a low mass at the east end the beds seem, though not very clearly, to be steep. Of the boulder-clay but little is left, and that is covered by blown sand, but the beds have the appearance of being deposited round the mass, not crushed up with it." On this occasion he also saw a mass of chalk, exposed at the base of the cliff and rising from the shore, some six or seven hundred yards on the Cromer side of the Trimingham headland, about seventeen yards long, and, so far as he

[1] We prefer this more general term to that of till, by which it has generally been designated in the Cromer sections. Though the latter is no longer used to imply an indubitable product of land ice (a very convenient distinction), some remnant of that connotation still clings to the word, and besides this we are unable to see in what important respect (except an occasional more distinct appearance of stratification) these glacial clays near Cromer differ from similar English deposits to the north, south, or west.

[2] Meaning such as is figured in the Memoir. Throughout we paid more attention to the western bluff (hence the above use of the singular) because the bent flint layers in that made it the mainstay of the hypothesis.

remembers, not more than four high, the beds of flint curving down very gently towards its eastern end. This mass had not been visible in 1898, nor was it in 1905, having probably been washed away in the interval.

We were again at Cromer in the Spring of 1900, and twice visited the Trimingham section.[1] The drift about the western chalk-mass was much obscured by washed down mud, but the curvature in the bands of flint was very distinct at the eastern end and less so at the western, though apparently in the latter case more acute than in the former. At the eastern chalk-mass a small 'cave' was seen high up on its western side between it and the drift, but the section was on the whole clearer on the opposite side. In this mass the flint bands were practically horizontal. Its top, rather wavy in outline, was covered by a thin irregular bed of coarse gravel, curving over its rounded corner. Then came sand enclosing a thin bed of laminated clay, followed by a rather thicker one of bluish-grey clay, and that by alternating beds of sand and clay, the whole being rather less than three yards in thickness. From the place where the edge of the chalk-mass plunged steeply downwards a crack extended vertically upwards into the drifts. The beds on the land side of this were to a considerable extent masked by 'wash-down,' but, so far as we could see, were not continuous with those on the other which have just been mentioned. Gravel was also seen to rest on a sort of ledge near the bottom of the chalk-mass, followed by a rather sandy band; this, by a thinner one of brown laminated loam, and it by a slightly thicker bed of sand, covered by a clay "resembling the thicker bed of bluish-grey clay seen at the top." This clay "contained some pebbles and bits of chalk besides flint, but was not quite identical with the usual boulder-clay."[2] There was also a small hollow in the steep shoulder of the chalk-mass filled with "laminated stuff, rather messed." As these beds curved upwards they might be cited to prove a bending simultaneous with that of the chalk. But unfortunately for this the lower set overlapped one another and ended against the chalk, while the flints in the latter afforded no evidence of curvature, but apparently dipped gently towards the south or south-south-west. The sea-face of the mass was then about 33 yards in length, its sides being also exposed to view. But on this occasion a third mass of chalk, about 12 yards long, was disclosed about 33 yards to the east of the last-named, on the top of which was the usual boulder-clay, of which a few feet were exposed.

[1] One of us (T. G. B.) records in his diary that this chalk-mass seemed to be included in the boulder-clay which cropped out on the shore about four yards to the west; that it contained *Belemnitella mucronata*, and that the flints, though rather discontinuous, seemed to form a C-like curve (on this detail, however, we were not quite agreed). He records chalk as exposed to west and to east of the eastern mass, but whether connected with it or as separate boulders could not be determined.

[2] Two varieties of boulder-clay occur in the Cromer district, one of a bluish-grey colour, another rather browner, more sandy, more distinctly stratified, and sometimes less pebbly. West of Cromer the latter is the commoner; east of it, on the whole, we think, the former, which is often the lower in position, but sometimes the one seems to pass into the other, or even to replace it.

Our final visit was in April last, when we found that the aspect of this part of the coast had been greatly altered by inroads of the sea. The western bluff (A),[1] so often noticed above, was now partly isolated, apparently reduced in length and height, and altered in shape, for another mass of chalk (C), almost separated from the former by a kind of passage, filled with the usual boulder-clay (B), had been disclosed to the south-west, roughly speaking. The south-western flank of this curved gradually down to the beach, as is well shown in the photograph, having a wedge-like termination, the lower side of which was seen to rest (D) on the usual greyish boulder-clay. Still more west and rather south of this, was a slab-like mass of chalk (E). As the two are only a few yards apart they might have a hidden connection underneath the beach, but we thought this improbable, for while they dipped on the whole towards each other, they did not appear to form part of a regular syncline. This last mass of chalk rests against and overlies the usual boulder-clay (F). In the remnant of the original western chalk-mass the flint bands showed, as we thought, a sharp curvature in the lower part of that face, and on its eastern one curves more like part of a quadrant. On this side a bed of chalky gravel rested against the landward face of the chalk, and parallel with the former was a distinctly stratified bed in the boulder-clay (that filling the 'tunnel'). These bands were parallel with the edge of the chalk and dipped seawards at a high angle. Also they made an angle of some 30° with the tangents to the curves of the flint layers at their nearest parts. Thus they can hardly be cited to prove a 'rucking up.' The chalk lintel of this portal varied irregularly in thickness from about a foot to about a yard, and seemed to be continuous,[2] but we came to the conclusion that this tunnelled mass of chalk was more probably formed by two distinct boulders, the wedge-like edge of one resting on the top of the other.[3] The eastern mass, which figured in our earlier descriptions, had now disappeared, unless it were represented by little more than a streak of chalky material at the base of the cliff, together with that which in 1900 we saw beyond it in the same direction.[4]

About a quarter of a mile nearer Mundesley two great boulders of chalk—respectively about sixty and thirty yards long, and about twenty feet high—were exposed in the cliff, rising from the shore,

[1] See Plate XXII, a reproduction of a photograph, taken shortly after our visit by Mr. R. T. Mallet, for which and several others of great interest we are indebted to his kindness. By the aid of this our description, we trust, will be intelligible to the reader.

[2] It was not accessible.

[3] Wedge-like ends are not uncommon in these great chalk boulders.

[4] In the neighbourhood of these masses, when the tide permitted (which sometimes it did not), we have seen chalk near one mass, clay near the other, but no proof that they are continuous with the chalk platform, which undoubtedly lies a very few feet below them. A memorandum sent us with the photograph by Mr. Mallet is important. "The foreground is a large mass of blue till, on the level top of which the camera was placed. It was about a foot above the sea at 4 p.m. on May 9th." (About an inch vertical of this foreground has not been reproduced in the Plate, for otherwise the scale must have been diminished.)

THE "WESTERLY CHALK BLUFF" AT TRIMINGHAM.

From a Photograph taken by R. T. Mullin, Esq.

the flint bands in which were nearly horizontal. On the top of each was a layer of coarse gravel, followed by much stratified sand with occasional bands of clay. The eastern of these boulders projected slightly in advance of the western one, and their ends, so far as the slipped material allowed us to determine, were about nine yards apart.[1] The clay just mentioned is not pebbly, but below high-water mark and perhaps eight feet vertically beneath the base of the cliff typical boulder-clay was exposed on the beach. About fifty yards to the east chalk showed up beneath this, and on it, as we walked in that direction, we saw for a considerable distance patches of boulder-clay. Evidently ancient denudation has removed the Forest Bed and *Leda myalis* sand from this part of the coast, so that for a considerable distance the bluish-grey boulder-clay rests on a very slightly irregular surface of chalk.

We may now mention one or two fundamental weaknesses which, to our minds, were inherent in Mr. Reid's hypothesis from the first, but had apparently escaped his notice. He offers his readers only one alternative to the action of an ice-sheet as an explanation of these chalk-masses either at Trimingham or where they are admittedly boulders, viz. transport by icebergs, and dismisses the latter on the ground that the sea, supposing it to have existed, would have been too shallow to be navigated by bergs of sufficient thickness to float such huge masses of rock. We do not dispute this objection, but are surprised to find that he has not discussed or even noticed Colonel Feilden's observations on the transporting power of an icefoot—i.e. of 'rafts' of ice—which were made in Smith Sound during Sir G. Nares' Arctic expedition.[2] Such rafts, as the chalk-masses need not have travelled far, would be much more probable vehicles than bergs.

Again, the reader must remember that the section in the Survey Memoir (p. 116) exhibiting the Trimingham mass as a second stage in boulder-making is only hypothetical, as its author virtually admits in the following sentences (p. 115) :—"If the ice-sheet, instead of flowing over the beds, happens to plough into or abut against them, it would bend up a boss of chalk, as at Beeston. A more extensive disturbance, like that at Trimingham, drives before it a long ridge of the beds, and nips up the chalk, till, like a cloth creased by the sliding of a heavy book, it is folded into an inverted anticlinal. A slight increase of pressure and the third stage is reached—the top of the anticlinal being entirely sheared off, the chalk boulder driven up an incline and forced into the overlying boulder-clays." An explanation no less clear than confident, but can any instance be cited which affords even an approach to a valid proof that either a large glacier or an ice-sheet can exercise this 'rooting' power on a fairly solid rock. Statements such as that just quoted are no doubt common; ice has been credited with the excavation of valleys, fjords, and important lake basins, but when

[1] A third and smaller chalk-mass was exposed in the cliff about twenty yards still further east.

[2] Quart. Journ. Geol. Soc., vol. xxxiv (1878), pp. 563–566.

we examine that still in existence, or the districts which it formerly covered, we find it has never done more to a limestone than mould its surface into mound-like masses, and has often preferred to let a gravel severely alone. In the Cromer district, as at Möen, Rügen, and the Isle of Wight, the chalk has undergone considerable flexure, but that this was done in Glacial times is nothing but an hypothesis, contrary to, rather than supported by, such evidence as can be obtained. We have more than once examined the chalk platform between Beeston Hill and Sheringham, and consider those little insulated outcrops of that rock, rising a yard or two above the beach, to be far more probably the indirect result of pre-Glacial, perhaps long pre-Glacial, disturbances, which were afterwards exposed to marine denudation probably in late Pliocene times. Even the case figured in the Survey Memoir (at the bottom of p. 115) is not in the least convincing. The Pliocene beds might have been deposited round an old bank of chalk, just as is shown in the section, and the fact that the higher of the flattened arches of flint comes to an end at the upper surface is more consistent with flexure followed by denudation than with the bending of a rock-mass, which had a practically level top and horizontal flint bands. Still less can it be proved that an ice-sheet has ever produced by its thrust an 'inverted anticlinal,' even in a rock no harder than chalk, or is competent entirely to shear off the top of that anticlinal. Allegations of such things can, no doubt, be produced by the dozen, but in all of which we know anything hypothesis takes the place of proof. Mr. Reid himself cites one (p. 115): "By Continental geologists the theory (we should call it hypothesis) has been already applied to the explanation of the even greater disturbances in the island of Möen in Denmark." So it has been at Rügen, which also we have carefully studied,[1] with the result that we found it difficult to treat the explanation seriously. Did we admit its validity we should be fully prepared to attribute the disturbances of the chalk at the Needles or Culver Cliffs to the thrust of an ice-sheet!

Perhaps, however, the huge and strangely-shaped boulder now visible in the cliffs between East and West Runton Gaps will be cited as a proof of the bending powers of an ice-sheet. Here a mass of chalk, which must once have been slab-like, after lying almost horizontally for some fifty yards at the bottom of the glacial deposits, bends rather suddenly[2] and runs rapidly up the cliff to within a short distance of the top. It is capped, as is not unusual with the Cromer erratics, by a band of coarse flint gravel, which can be seen, at any rate for a considerable distance, to be bent up with the chalk. This mass, we may be told, has been sheared off, thrust against some obstacle, and finally bent up by the advancing ice-sheet. If so, the direction of the axis of the curve shows that

[1] Quart. Journ. Geol. Soc., vol. lv (1899), p. 305, and vol. lvii (1901), p. 1.

[2] It takes the shape of a fairly open hook, the two arms forming rather less than a right angle; the 'horizontal' part of it slopes slightly westward; a thin extension of a rather sandy boulder-clay dies out beneath it, and then the chalk probably touches (this part was masked by some talus) the *Leda myalis* sand.

ice-sheet to have been coming from somewhere between west and south rather than north or east—a mighty volume of frozen water, not from Scandinavia or Scotland, but from the mountainous region which environs the Wash!

We conclude by recapitulating, in addition to these more general objections, the heads of the evidence, which, as shown above, we have collected during our visits, and find irreconcilable with Mr. Reid's hypothesis:—

(1) The bending of the chalk, as shown by the flint bands, is very variable (notably at Trimingham headland), and not seldom practically disappears, affording no evidence of regularity of distribution.

(2) The chalk in immediate association with the glacial drift does not occur, even at Trimingham, as a continuous mass, but in separate fragments.

(3) The bedding of the drift, where in contact with the chalk, is generally almost, if not quite, horizontal; at any rate, it shows that this lower part cannot have been crushed up *with* the chalk.

(4) But above these horizontal beds others may occur which are contorted, and sometimes to an extraordinary extent. Thus their flexures must be due to some other cause than that which Mr. Reid invokes to produce the bending and uprooting of the chalk and immediately adjacent drift; for if a second advance of the ice-sheet be postulated in explanation of these, it was content, on the second occasion, to leave the drift below it undisturbed.

(5) Lastly, chalk-masses occur east and west of Trimingham headland, insulated, like great erratics, in the drift without any appearance of crumpling up, so those at that place do not demand a special explanation.

Thus Time, as we venture to maintain, has delivered its verdict against an hypothetical interpretation of these Trimingham masses, which in our opinion ought not to have found a place in a Survey memoir. They are simply huge boulders, like the other chalk masses east and west of Cromer. We have, of course, adopted for our own use an explanation of these and of the extraordinary contortions of the drift; but as we do not yet exalt it from hypothesis to theory, and as the purpose of this paper is destructive rather than constructive, we think that any definite statement of it would be unnecessary.

III.—Notes on some Rocks from New Zealand.

By R. H. Rastall, B.A., F.G.S., Christ's College, Cambridge.

THE specimens on which the following notes are based were collected by Mr. H. T. Ferrar, M.A., F.G.S., while on a tour through New Zealand, during the time the "Discovery" was being overhauled in Lyttelton, on her return from the Antarctic. The topographical and field notes were also supplied by Mr. Ferrar, and it must be clearly understood that only the detailed petrographical descriptions are the work of the present writer.

The specimens were obtained near the middle of the North Island of New Zealand, and in the area marked "acidic volcanic rocks" in Sir James Hector's geological map of New Zealand, published in 1883. They all occur in the Taupo zone, the hot-lake district which lies roughly between Lake Taupo on the south and Lake Rotorua on the north.

The following descriptions are written from thin slices cut from Mr. Ferrar's specimens, which were necessarily small, owing to difficulties of transport. The numbering adopted is purely arbitrary, and has no reference to sequence or supposed relative age.

1. *Waiora Valley.*

The Waiora Valley commences in a crater-like depression the walls of which consist of rock No. 61. This depression is about half a mile in diameter, and the walls rise in places to a height of 300 feet. In the centre of the depression there are abundant fumaroles, which deposit sulphur; also pools of boiling muddy water and steam vents; these are causing rapid disintegration of the surrounding rocks.

No. 61. Waiora Valley, Wairaki. This is a dark bluish-grey and rather vesicular rock with distinct porphyritic structure. The conspicuous porphyritic elements are a plagioclase felspar and prisms of pyroxene in a fine-textured groundmass.

The felspar crystals are prismatic or tabular in form and about 4 mm. in length. They are sometimes slightly rounded and show zones of glass inclusions. Zonary banding and twinning on the albite law are conspicuous, and the extinction angles measured on the twin lamellæ are as high as 30° in the interior of the crystals, and nearly 0° in the outer zones, so that the felspar ranges from labradorite to oligoclase. On the average it is of an intermediate composition. The pyroxenes include both colourless augite and pale brown hypersthene with slight pleochroism. The augite is the more abundant. The groundmass consists of a felted aggregate of small irregular prisms of felspar, with a little interstitial glass, the typical hyalopilitic structure of Rosenbusch. It also contains very numerous minute cubes of magnetite.

This rock is therefore a very typical hypersthene-augite-andesite.

2. *Aratiatia Rapids.*

On the Waikato River a series of volcanic rocks crop out through the covering of pumice fragments which cloaks the land. They strike approximately east and west, and the dip is about 60° to the south. The river crosses the strike perpendicularly, and has cut a narrow gorge with sides some 200 feet high. The series is over 1,000 feet thick, and the specimens were collected from the harder bands, which are usually each about 100 feet thick. The foot of the rapids seems to be also the base of the series, and the specimens are described in ascending order.

Nos. 64 and 62 are parts of the same mass of rock near the north

and lower side of the rapids. No. 63 was obtained near the middle of the rapids and about a quarter of a mile above No. 62. No. 65 is about a quarter of a mile higher up, and No. 66 is again about the same distance above No. 65. No. 67 was taken from an exposure on the roadside above the rapids and about a mile south of No. 62.

No. 64. A very vesicular rock with a few porphyritic crystals set in a groundmass of reddish and yellowish glass, showing remarkably fine flow-structure.

The phenocrysts are chiefly a slightly zoned plagioclase with a narrow extinction near to oligoclase; but there are also one or two crystals of a remarkable and interesting femic mineral. This occurs in the eight-sided prisms characteristic of the pyroxenes, but its cleavages are unfortunately very indistinct. In colour it is a rather deep reddish-brown and distinctly pleochroic; each crystal has a border of a much deeper colour. The extinction angle is high, up to 40°. More material is required before the mineral can be identified with certainty, but it appears to be a monoclinic pyroxene, very rich in iron, and may possibly be the dimorphous form corresponding to the rhombic ferriferous pyroxene amblystegite. The deep red border may be only a separation of ferric oxide, but its appearance strongly recalls that of the peculiar soda-iron-amphibole, cossyrite, in the Pantellarites. The border is narrow and too opaque for its optical properties to be determinable.

The bulk of the rock consists of a very vesicular glass, varying from colourless to yellow or pale reddish-brown, and showing very fine flow-structures. This encloses a good many minute prisms of felspar. Occasional roundish patches of minute felspar prisms seem to be due to devitrification. A good deal of the glass shows a fragmentary appearance suggesting the inclusion of lumps of glassy tuff in a lava while in motion.

No. 62 is a pink rock very similar to the last, but in addition to the peculiar mineral described above it shows several well-developed prisms of a brownish pyroxene, with a dark border, strong pleochroism, and straight extinction, which may be identified as amblystegite. These two rocks must be regarded as mixtures of lava and tuff of very similar composition, probably indicating a rain of fragments into a lava-flow while still fluid.

No. 63. A markedly spherulitic rock with a few phenocrysts of a zoned plagioclase felspar; coloured minerals are absent, except for a few grains of magnetite. The spherulites may be as much as 3 mm. in diameter, and consist of long regular radiating prisms of felspar, giving a good black cross. They seem to be due to devitrification, since flow-structures, indicated by lines of crystallites, pass through them. This rock also contains rounded lumps of glass of slightly different structure.

No. 65 is practically identical with the last, the only differences being that flow-structure is more pronounced and the spherulites are larger, up to 5 mm. in diameter.

In No. 66 spherulitic and perlitic structures are both very strongly marked, and perlitic cracks pass through the spherulites.

No. 67 is a grey, markedly porphyritic rock with large phenocrysts of plagioclase felspars and a little femic material in a fine-textured groundmass. The felspar is of the usual zoned type, and ranges from andesine to oligoclase. The coloured minerals include both oblique and rhombic pyroxenes, but the latter is dominant; it is very pale brown and slightly pleochroic, so that it must be classed as hypersthene.

The groundmass may on the whole be described as of the hyalopilitic type, but the prisms are not so well defined as usual, and there is a good deal of glass. This rock is a hypersthene-augite-andesite, and strongly resembles the specimen from the Waiora Valley, No. 61.

3. *Huka Falls, near Taupo Lake.*

This rock has horizontal joints, and gives rise to a waterfall some 150 feet high. Its connection with the other rocks of the district is obscured by the post-Tertiary [1] cloak of pumiceous débris.

This is another glassy rock, with rather abundant broken plagioclase crystals and some quartz in a groundmass of fragments of vesicular glass, showing good flow-structures. Coloured minerals are very rare. It is probably more acid than those described above, and may be regarded as a rhyolite tuff.

4. *Tarawera.*

No. 69 was obtained in a roadside cutting near the buried village at the west end of Lake Tarawera, and is said to have been ejected during the great eruption of 1886.

It is composed of fragments of glass, with very fine flow-structures and perlitic cracks, and the usual plagioclase crystals are often broken. There are also several well-formed crystals of a mineral with the characters of a pyroxene, pale brown and slightly pleochroic, with an extinction angle as high as 45° (cf. Nos. 62 and 64). The structure of the rock is clearly pyroclastic.

Conclusion.

Owing to the small amount of material at my disposal it is not possible to draw any very definite conclusions as to the character of these rocks. On the whole there is a considerable family likeness between the different types, and they seem to form a series of pyroxene andesites and rather basic pitchstones. The rock from Huka Falls is more acid and probably of rhyolitic composition. In many cases it is possible to distinguish a more or less distinct fragmental structure, and some are tuffs, or at any rate a mixture of lava and tuff.

The general mineralogical composition suggests that they belong to the subalkaline family, and they contain pyroxenes of a rather unusual type.

[1] See Hector's map.

IV.—The Recent Geological History of the Baltic. Part III: The Western part of the Sea, the Sound, and the Belts.

By Sir H. H. Howorth, F.R.S., F.G.S.

In two previous papers I have set out the conclusions generally held by Northern geologists in regard to the more recent history of the Eastern Baltic, according to which it was once a great enclosed fresh-water lake or sea, the *Ancylus* lake, which by the breach in the land-bridge connecting Skäne and Denmark was converted into a brackish-water sea, the *Litorina* sea, which has in turn become less and less saline until it has reached its present condition.

In the second of these papers I quoted a number of facts proving the breach just mentioned. Before I turn to another chapter of the interesting history, I propose to add to these facts, and to show more conclusively that the whole coast of the Southern Baltic is an area of depression where evidences of the subsidence of the land in recent times are general and consistent, and where, so far as we know, this subsidence while in progress was not qualified by any partial or intermittent upheaval. I shall quote some additional facts in this behalf from Hahn's memoir entitled "Untersuchungen ueber das Aufsteigen und Sinken der Küsten" (Leipzig, 1879). He first quotes the observations of Berendt that in the delta of the Niemen the land has sunk so much and become so marshy that where, as is attested by Church-records, as late as 1576 forests of oak grew, no such trees will now grow because of the wet nature of the ground. He also quotes numerous cases of sunken peat bogs, attesting the same fact. Thus, west of Labiau there are found at a depth of 3·1 metres remains of a submarine forest with pieces of coal among the trees, and near Schwarzort in the Kurische-Nehrung at a depth of 6·2 metres have been found ornaments of amber, showing that a considerable subsidence has taken place in the human period.

An old stone sea-wall at Fielenhof on the so-called Windenburger Ecke, which is not more than 110 to 115 years old and which was erected to protect a garden against the sea, is now overflowed. A lawsuit between the fiscal authorities and the inhabitants has shown that some islands covered with reeds and rushes in the haven were not long ago parts of the mainland, and were not detached by a gradual process of eating away, but by a rapid overwhelming by the water.

In the Kurische-haff the water has so encroached that the distance between it and the so-called 'Grossen Friedrichsgraben' has greatly diminished. The foundations of the old Kurhaus of Cranz are now under the sea, and the land there is said to lose 1·89 metres a year—this, be it remarked, in an enclosed bay where there is no tide. Rugen and the small islands round it have become considerably smaller in late years.

Submerged forests occur along the coast of Pomerania, near Köslin, between Rator and Lieps, in Rugen at Lindenhaken, and the Lobber Schaar (the Monks estate). The Mecklenburg coast, as far

as Wismar and beyond, is broken by a number of inlets, apparently due to subsidence. At Travemünde are two great blocks of stone which are now in the water, but which the sea had not reached at the end of the eighteenth century. At Heiligenhaf and the island of Fehmarn we again meet with submerged forests, and at the eastern outlet of the Fehmarn Sound are remains of an ancient wall. The whole coast of Schleswig-Holstein bears similar traces, *inter alia* the worn island of Werder, near Heiligenhaf. The former perch-frequenting inland lake on the coast at Probstei is no longer a lake, but an arm of the sea. The ancient hunting lodge of Bramhorst on the same coast has disappeared, while the trunks of the trees in the wood which once surrounded it are now submerged as far out as five hundred paces from the shore. The castle of Altbulk on the north side of the harbour of Kiel did not when it was built stand as it does now, on the edge of the water. The Wurdebye Noer, near Eckenförde, has all the appearance of having formerly been a lake. It is now an arm of the sea. According to V. Maack the remains of the Schleimunder Burg at the mouth of the Schlei are now under water. The island of Oehe, north of the mouth of the Schlei, was formerly a peninsula, and the peninsula of Maasholm on the south side of the same is rapidly becoming an island. V. Maack calls attention to the haven of Dywig or Ducwig on the north-west coast of Alsen (near Norburg), which was once a lake. The Slipsee and the Bankeldam, between Apenrade and Hadersleben, are examples of the same kind, as is the inlet of Heilsmunde on the Danish frontier (op. cit., pp. 162–165).

Örsted, in his monograph on the fauna of the Sound, to be presently referred to, speaks of submergences having taken place at Vedbœk, between Sletten and Humlebœk, and at Sledkersteen, both on the coast of Zealand, attested by the reports of fishermen who had noticed trunks of trees with their roots in the ground in the sea far from the shore (op. cit., p. 18).

K. Rördam, in his memoir entitled "Salt vandsalluviet i det nordostlige Sjaelland," has shown in a map the large area which was depressed in that part of Denmark in recent times, especially in so far as the depression affected its great fiords, notably the Isefiord and the Roskildefiord, and the two once submerged bogs known as the Store and Lille Törvegrund, south of Frederiksvaerk; and he mentions how in the Sound at Charlottenlund, opposite the restaurant of Constantia, there is a submarine turbary two metres under the water.

He also describes several peat bogs now above sea-level, but underlying beds of the *Litorina* time, on the coast of Zealand, as proving the same fact. Thus, in a turf bed a quarter of a mile north of Skuldelev, called Mosejord, there is a bed of clay 2·5 feet thick, containing *Cardium edule* and *Nassa reticulata*, overlying one of turf with remains of oak, birch, juniper-berries, and fruit of the buck bean. Another peat bog at Herslev shows a bed of meadow-soil covering marl, without shells, then a layer with many beach shells, lastly a bed of the same kind of turf as that at Skuldelev.

At Nivaafiord, the innermost part of Esromfiord, the fiord of Raageleje, the Ramlösifiord, and the Nörremose, near Kregome, and in many spots in the old fiords of Skuldelev and Selsö, similar phenomena have been forthcoming as the result of excavations and borings. Thus, at Hovenge, 2,800 feet south-east of Brandbjerggaard in Selsö Sogn, V. Madsen reports a section consisting, in descending order, of mould, turf, fresh-water loams with fresh-water shells, and then a bed with salt-water fauna, comprising *Tapes aureus*, *T. pullastra*, *Cardium exiguum*, and *Rissoa inconspicua*, also containing leaves of oak, willow, and hazel-nuts, then gravel, then turf again.

At Hovenge, 1,200 feet south-west of St. Olaf's Church in Selsö Sogn, a *Cardium* mud with many salt-water mollusca overlies peat with remnants of the fir-tree. Eight hundred feet north-east of Buskbjerg in Skuldelev Sogn is a deposit of mould overlying *Cardium* mud with *Ostrea edulis*, *Scrobicularia piperata*, *Cerithium reticulatum*, *Rissoa membranacea*, *Litorina rudis*, *L. obtusata*, which again overlies turf with remnants of the fir. Eighteen hundred feet east of Östby in Selsö Sogn is a sandy turf, then marine sand underlaid by clayey sand, and this by *Cardium* mud with *Nassa reticulata*, *Litorina litorea*, *rudis* var. *tenebrosa*, and *Scrobicularia piperata*, and this again by a great peat bog with *Corylus avellana* and *Betula odorata* (op. cit., pp. 126–128).

As evidences of the former sinking of the land in North Jutland, which was then followed by a rise, are the two so-called wild moors. The smaller one is south of the eastern outlet of the Lim Fiord and the larger one north of Aalborg. The springs in the neighbourhood of the latter were in Forchhammer's time still brackish or saline.

When we cross over into Skäne similar evidences of beds of recent marine shells, now several feet above high-water mark and lying upon beds of a subærial type consisting of turf with fresh-water and land shells, abound. I referred in my previous paper to the notorious instance of the so-called Jära wall, in which this phenomenon is conspicuous.

Again, about a mile south of Helsingborg there is a bed 500 feet broad lying along the coast, and bounded on the land side by a steep slope of from 30 to 40 feet high. This steep slope is formed of fine limey laminated sand, arranged horizontally and nearly a foot in depth, which is overlaid by a definite layer of grey clay. A few shell fragments have been found in the clay.

The bed which lies between this slope and the sea is formed of several layers, the uppermost of which, 3–3·5 feet in depth, is formed of sandy gravel which the Swedes call 'strandgrus.' The gravel consists partly of angular and partly of rolled dissimilar rocks, among which are a large number made up of chalk and flint, together with frequent whole and broken shells of *Cardium* and *Mytilus*. This can be no other than the representative of the *Litorina* beds, and below it we find in due position the representative of a subærial bed of turf. Next we have a bed 1·5 feet thick of yellow-grey loam

containing abundant fresh-water shells, among which the following have been collected: *Planorbis complanatus*, *Bythinia tentaculata*, *Limnæa limosa*, *L. ovata-normalis*, *Valvata cristata*, *V. piscinalis*, and an *Anodonta*. Below this, again, is a bed of turf a foot thick, containing partly branches and partly stumps of oak-trees (Erdmann, Geol. För. i Stock. Förh., i, p. 93, etc.).

Erdmann, in the second volume of the Geol. För. i Stock. Förh., gives several other instances of beds in the neighbourhood of Malmö and Lund, notably at Hildesborg (a mile from Landskrona), at Bjerred (a mile west of Lund), and at Barsebäck (1½ miles south-east of Landskrona), where in sections, several feet thick, layers of marine sand and gravel occur, containing fragments of dwarfed forms of *Cardium* and *Mya* with thin shells, and lying on terrestrial deposits several feet above the present Sound (vide op. cit., vol. ii, pp. 97, 98, etc., etc.), all concurring to the same conclusion—that a recent submergence along all this coast has been followed by a recent upheaval.

Another remarkable evidence of the submergence we are discussing is afforded by the Zealand river Nivaa, now a small stream, but whose former course, says Rördam, can be traced at least for a distance of 3 kilometres beyond the borders of the Sound, which shows that here the ground had sunk to the extent at least of 8 metres, while on the opposite side of the Sound De Geer calculated that it had once sunk 15·5 metres (Rördam, op. cit., p. 131).

It is perfectly plain from this unanimous and most consistent geological testimony that there has been a great and notable and recent breakdown and submergence in various parts of the area now occupied by the Danish archipelago, where it is claimed the land-bridge recently existed which cut off the connection of the North Sea with the Baltic.

The breach in this connection, as we have seen, greatly affected the hydrographical character of the Eastern Baltic, and especially affected its molluscan and other fauna by converting what was previously a fresh-water lake into a brackish sea. In pursuing this induction in the previous papers, I limited my examination of the lessons taught by the Baltic fauna to those presented by its eastern section and to that portion of the sea lying to the east of the longitude of the island of Bornholm. I now propose to examine in some detail the fauna of the Western Baltic and its three great waterways, and to collect some scattered facts which may be useful to others besides geologists, and which greatly strengthen the case, especially on its chronological side.

I propose to begin with a conspectus or general balance-sheet of the living molluscan life in the Southern Baltic, and to show its accretion as we move westwards. According to Middendorf (Bull. phys. Math. St. Petersb., 1850, viii, p. 65) and A. Hensche (Schrift. Phys. Oec. Gesch. Königsberg, 1861, p. 90), there are only six marine shells in the eastern section of the Baltic: *Hydrobia balthica* (*Rissoa ulvæ* ?), *Neritina fluviatilis*, *Mytilus edulis*, *Mya arenaria*, *Tellina solidula*, and *Cardium edule*. Of other marine

invertebrates from thence we also have *Medusa aurita*, *Cyanea capillata*, *Gammarus*, and *Idotea entomon*.

Let us now move westward. A good test of the poverty of the Baltic in marine life in the longitude of Bornholm is afforded by the following list of the result of a fortnight's careful dredging on both the east and west of the island by a collector employed by Meyer named George Holm, in 1863, and containing a list *of all animal forms*, living or dead, he came across while dredging, except fishes and Protozoa. (See Mey. & Möb., "Fauna der Kieler Bucht," i, xx.)

Succinea oblonga.
Neritina fluviatilis.
Rissoa ulvæ.
Pontolimax capitatus.
Litorina litorea.
Mytilus edulis.
Cardium edule.
Tellina solidula.
Sarcochitum polygonum.
Piscicola sp.
Nereis diversicolor.
Spirorbis nautiloides.
Planaria torva.
Dendrocœlum lacteum.
Palæmon squilla.
Crangon vulgaris.
Mysis flexuosa.
Gammarus locusta.
Idotea tricuspidata.
Sphæroma sp.
Jæra sp.
Larvæ of *Phryganea*, and three different kinds of *Diptera*.

The shells reported from the sea between Moen, Stevns, the south coast of Skäne, Bornholm, and Rugen are :—

Utriculus obtusus.
Hydrobia ulvæ.
Litorina rudis.
Astarte borealis (? *elliptica*).
A. compressa.
Mya arenaria.
Macoma (*Tellina*) *calcarea.*
M. balthica.
Cardium exiguum (var.).
C. edule.
Mytilus edulis.

(Petersen, "Om de Skalbarende Mollusken udbredningsfolhold i de Danske haven, etc.," p. 42.)

According to Munthe, the two species of *Astarte* from this part of the Baltic, which he identifies as *A. borealis* and *A. elliptica*, are of diminutive growth, and live there therefore under unfavourable conditions. There cannot be any doubt, he adds, that they migrated to the Baltic after the *Ancylus* time (Bull. Geol. Inst. Ups., ii, pp. 14, 15). *Litorina litorea*, according to Munthe, also occurs in the Rugen waters, while *Scrobicularia piperata* and *alba* are reported from the mainland opposite Rugen at Greifswald. K. Brandt says that to the east of Rugen there are no sponges or Tunicates, only one Bryozoan, namely, *Membranipora pilosa* (var. *membranacea*), and one Cirripede, i.e. *Balanus improvisus*.

The straits between Gjedserode, in the island of Falster, and Darsserort, on the mainland of Mecklenburg, seem to form a considerable barrier to the eastern migration of submarine forms, and west of the straits the life becomes decidedly richer.

In 1889 Dr. Max Braun published a paper on the fauna, except the Polyzoa, of Wismar harbour in the Archiv Nat. Hist. Soc. Mecklenburg. In this he gives, *inter alia*, a list of the mollusca which had been found there, as follows :—

LAMELLIBRANCHIATA.

Mytilus edulis.
Modiolaria discors.
Cardium edule.
C. exiguum.
C. fasciatum.
Astarte borealis.
Tellina balthica.
Scrobicularia piperata.
Mya arenaria.

OPISTHOBRANCHIA.

Odontostoma rissoides.

PROSOBRANCHIATA.

Litorina litorea.
L. obtusata.
L. rudis.
Lacuna divaricata.
L. pallidula.
Rissoa octona.
Rissoa membranacea.
R. cornea.
R. parva.
Hydrobia ventrosa.
Neritina fluviatilis.

A much richer fauna occurs on the western seaboard of Mecklenburg. Thus, Dr. Heinrich Lenz contributed a memoir on the mollusca of the Travemünde or Lubeck Sound, to the great collection of materials published by the Commission of the German Government on the Baltic, from which I take the following list of molluscs (op. cit., iv, p. 170) :—

Mytilus edulis.
Modiolaria discors.
Montacuta bidentata.
Cardium edule.
C. fasciatum.
Astarte borealis.
A. sulcata.
Cyprina islandica.
Tellina balthica.
Scrobicularia piperata.
S. alba.
Solen pellucidus.
Corbula gibba.
Mya arenaria.
Saxicava rugosa.
Pholas candida.
Teredo navalis.
Æolis Drummondi.
Æ. rufobranchialis.
Polycera ocellata.
Doris pilosa.
Doris proxima.
D. muricata.
Utriculus obtusus.
U. truncatulus.
Odostomia rissoides.
Litorina litorea.
L. obtusata.
L. rudis.
Lacuna divaricata.
L. pallidula.
Rissoa inconspicua.
R. membranacea.
R. octona.
Hydrobia ulvæ.
H. ventrosa.
Cerithium reticulatum.
Buccinum undatum.
Nassa reticulata.
Fusus antiquus.
Neritina fluviatilis.
Loligo breviceps.

Braun makes a general comparison between the marine fauna of Wismar and of the Lubeck inlet, which is interesting as showing how local conditions determine problems of distribution, even under such similar surroundings. Thus, he says, 31 species of marine animals occur at Wismar which are not found in the Lubeck gulf, namely: *Podocoryne carnea, Sagitta germanica,* all the Rotatoria, *Polynoe squamata, Valkeria cuscuta, Dias discaudatus* and seven other Copepods, *Podon minutus,* three Ostracods, three forms of Amphipods; and among the molluscs, *Cardium exiguum, Odontostoma rissoides, Rissoa cornea* and *parva*; and lastly, *Oikopleura flabellum.* These are chiefly small pelagic forms, some of which were naturally overlooked by Lenz.

On the other hand, there are wanting many forms at Wismar, found by Lenz at Travemünde. He mentions 137 species from Lubeck, while there are only 101 at Wismar. Only 70 species are common to both places, and 67 are peculiar to the Lubeck district, namely :—

Sponges	2
Coelenterata	7
Echinodermata	1
Vermes	17
Bryozoa	2
Crustacea	12
Mollusca	24
Tunicata	2
	—67

Most of these, Braun holds, have their furthest eastern limit in the Travemünde or Lubeck district, while Wismar itself seems to be the furthest eastern limit of many others.

(*To be concluded in our next Number.*)

REVIEWS.

I. — The Geology of South Africa. By F. H. Hatch and G. S. Corstorphine. 8vo ; pp. 348 and xiv. (London : Macmillan & Co., 1905. Price 21*s.* net.)

THE discovery of gold and diamonds in the Transvaal has been the parent of many literary prodigies, some great, some small, but mostly of the mouse-like kind. Among the latter, papers on the origin of gold in the banket, the extension of the main reef, and countless pamphlets on the geology of the Transvaal form a conspicuous feature.

The authors of the present work attempt to collect into a small compass the varied sources of information relating to the geology of the Transvaal, and to a less degree that of South Africa as a whole. Those acquainted with the literature of the subject will admit that they have succeeded in producing a clever abstract of a most bewildering subject. Those fresh to the enquiry will be spared the trouble of digesting much dead matter, or if they desire to do so they may consult the bibliography given at the end of the volume.

Reviewing the book as a whole, its prominent feature lies in the small space into which the authors have skilfully compressed most of the essential problems dealing with the geology of a vast tract of country. One is horrified to think how many volumes a studious German might have filled and yet not have advanced our knowledge of the subject any further, if so far. Several years' practical acquaintance with the geology of South Africa has enabled the authors to avoid the pitfall of voluminosity. They have, perhaps, not altogether escaped the unaccountable mesmerism that diamantiferous deposits seem to exercise on the skilled and unskilled mind. On the other hand, important dynamical and physical problems are

almost entirely ignored, at which the scientific man will lament, but the practical man rejoice.

The book is divided into three parts. Part i deals with the Pre-Karroo rocks. Owing to the want in similarity of the succession in different areas this portion has been divided into two sections. Section 1 describes the Pre-Karroo rocks of Southern Cape Colony, a subject already and more fully treated of by Mr. A. W. Rogers. It, however, forms a suitable and necessary introduction to Section 2, which gives an excellent and clear account of the Pre-Karroo rocks of the Transvaal, together with brief descriptions of these rocks in the remaining portions of South Africa. The advance made in determining the puzzling stratigraphical sequence of several unconformable and unfossiliferous formations will be gathered from a comparison of the authors' conclusions with the latest published results (1904) of Dr. Molengraaff. The origin of the gold in the banket is seriously discussed. The authors adopt the theory of subsequent infiltration.

The Karroo and Post-Karroo rocks receive sufficient attention in parts ii and iii. Part iv, describing the volcanic rocks of doubtful origin, contains a chapter of 29 pages on the diamond-bearing deposits.

The correlation of the various rock groups in part v deserves the closest attention. This difficult question is clearly and philosophically placed before the reader, who can gather in brief what permanent results have been obtained and in what direction future work lies. We may state that this portion could only have been written by one intimately acquainted with the recent results obtained in Cape Colony, and shows the value of the work accomplished by the surveyors in those regions.

In the way of print and illustrations of fossils and rock scenery nothing remains to be desired. Two excellent geological maps, printed in colour, afford the reader the means of following the authors' descriptions of the different regions. The introduction of various tints of black and grey for the Karroo deposits does not seem a happy one. Since the Karroo beds range from the Carboniferous to the Jurassic it is scientifically incorrect; while experience in this country has proved such colours to be artistically hopeless. We trust they will not receive official sanction. W. G.

II.—Ninth Annual Report of the Geological Commission of the Colony of the Cape of Good Hope, 1904.

THIS report contains a full account of the progress made during the year 1904. In completeness of detail, and in the number of the accompanying illustrations and maps, it should be classed as a memoir rather than as a report.

In the Chairman's letter, and in the introduction by the Director, it is stated that the work of the Survey was hampered by lack of funds, so that important districts could not be visited owing to the cost of hired transport. Throughout the present report we read how the welfare of the colony largely depends on the water supply obtained from wells and borings. It therefore seems surprising

that this useful survey of the rock formations is not being pushed on irrespective of cost. Engineers visiting South Africa have acknowledged the value of the work accomplished by the Commission, and the present report shows that the officers of the staff pay especial attention to this all-important subject. Surely the most 'practical' of men cannot fail to see the necessity of knowing the order of succession, distribution, and structure of the rock formations, for on these the success or failure of boring for water, as well as the search for minerals, essentially depends. Let us hope that the Commission will be afforded greater facilities for continuing their work on the same sure grounds with which it has been and is being conducted.

In the present report a useful, if somewhat brief, summary by the Director, Mr. A. W. Rogers, precedes the detailed account of the areas examined. A table of strata of the succession in Cape Colony, with their probable European equivalents, is here given, but without comment. We note, however, that the table is to be regarded as that used at present by the Survey. Evidently, then, alterations and additions may be expected as the field-work proceeds.

The detailed portion of the report includes a description of the geology of the north-western part of Van Rhyn's Dorp by the Director. The discovery of another set of rocks, termed the Nieuwerust Series, shows how much remains to be done before South African stratigraphy is reduced to something like order. This series, consisting of arkose, quartzite, and slate, is regarded as later in age than the Malmesbury Beds, granite, and the Ibiquas Series.

The descriptive account of the geology of Long Kloof, by E. H. L. Schwarz, shows that here we are dealing with a highly folded region, as to the nature of which Mr. Schwarz offers some interesting suggestions.

Mr. A. L. du Toit presents a very detailed and interesting account of the geology of Aliwal North, Herschel, Barkly East, and part of Wodehouse. Considerable additions are made to our knowledge of the Karroo Series. Mr. Du Toit finds it possible, on palæontological evidence, to divide the great thickness of the Beaufort Series into two portions. For the upper portion he proposes the name "Burghersdorp Beds." Besides being characterized by a special reptilian fauna, they are further interesting from the occurrence of *Glossopteris* and Lepidodendroid stems in association with *Thinnfeldia*. In the account of the volcanic beds of the Stormberg Series, descriptions are given of over sixty volcanoes occurring in Wodehouse, Barkly East, and Herschel; while descriptions of others in Aliwal North are promised. This evidence of powerful vulcanicity is unique in the Jurassic period of the earth's history.

A special feature of the report consists in the welcome addition of numerous black and white maps illustrating the areas described. The want of headlines, a fuller table of list of contents, and a more copious index will be felt by the general reader. Some of the figures, too, are without accompanying scales, and the frequent inclusion of their descriptive indices in the text becomes exasperating.

These are, however, minor faults, easily capable of remedy, but detailed perfection cannot be expected from a small and sadly hampered staff. We must be content with the evident skill and honesty of purpose which has marked the work of the Commission during the year included in this report and in those preceding.

W. G.

MEMOIRS OF THE GEOLOGICAL SURVEY OF ENGLAND AND WALES.

III.—THE GEOLOGY OF THE COUNTRY BETWEEN DERBY, BURTON-ON-TRENT, ASHBY-DE-LA-ZOUCH, AND LOUGHBOROUGH (EXPLANATION OF SHEET 141). By C. E. FOX-STRANGWAYS, F.G.S., with a Chapter on Charnwood Forest by Professor W. W. WATTS, M.A., M.Sc., F.R.S. 8vo; pp. 83. (London, 1905: E. Stanford, 12, 13, and 14, Long Acre. Price 2*s*.)

THE area described in this memoir contains a number of small inliers of pre-Cambrian rocks belonging to the Charnwood Forest complex, which are dealt with by Professor W. W. Watts, who described the pre-Cambrian of Charnwood Forest in the memoir dealing with the region to the south (155).

The next formation in the succession is the Carboniferous Limestone, represented by a few inliers situated on a continuation of the Charnian axis. Although covering only a small area this rock has yielded a large number of fossils, and a list of over a hundred species identified by Dr. F. L. Kitchin is given. Above the limestone are the limestone shales seen at Ticknall, Dimminsdale, and Calke. They have thinned out from 5,000 feet in Derbyshire to some 500 feet at Breedon, and are probably still less on the flanks of Charnwood. The Millstone Grit above has been divided into three divisions, which are, however, not very persistent. There is a general diminution in the coarseness of the grains from below upwards, the lower beds being generally conglomeratic, the middle grits, and the upper fine-grained thin-bedded sandstones. The formation contains a plentiful supply of good water, now utilised by Melbourne, Castle Donington, Long Eaton, and other places.

Much of the detailed information relating to the Coal-measures is reserved for a memoir on the Leicestershire Coalfield. There are here given, however, two tables showing the thickness of the seams and the intervening measures.

Certain purple marls and breccias with a little sandstone, coming between the Carboniferous and the Trias, are doubtfully referred to the Permian (as in the old memoir) in the absence of evidence to the contrary.

The Bunter occurs only as pebble-beds in this area, the Lower Soft and Upper Soft Sandstones being either absent or represented by pebble-beds. They are well exposed round the west and north sides of the coalfield, overlapping the beds called Permian, but are not very thick. They are better developed further north, between Bretby and Foremark, where they form the sides of the valleys. The Bunter is followed by the Lower Keuper sandstone and marls, from about 50 to 100 feet thick, thinning towards the north. Beds

of breccia occur at the base, well seen at Castle Donington. A considerable area is covered by these beds to the south of the Trent. Between Griffydam and the Charnwood Hills the basal breccia becomes much more developed, replacing a great deal of the sandstone. It rests here on Coal-measures, and is unaffected by a large fault below. The Keuper marls, which come next, occupy a larger area than any other formation, covering three-fourths of the map. As a general rule they pass down into the sandstones below, but overlap them in the neighbourhood of the old land surface of the Charnwood Hills. They are lithologically red and grey marls, with thin unimportant bands of white sandstone, only one, south of Castle Donington, being worth mapping. The marls contain beds of gypsum worked at Chellaston and Gotham.

Three patches of Lias, with narrow outcrops of Rhætic at their bases, occur. The one at Normanton is a spur of the main mass of Lias in the next sheet to the east; the other two, at Gotham and West Leake, are outliers. The Rhætic consist of about 20 feet of dark laminated shales resting on tea-green marl. Above is grey shale with thin limestones passing up into Lias. A collection of fossils from the Normanton tunnel has been described by Mr. Montagu Browne.

The Drift is much thinner and less important than in the sheet to the south. It is found to cap the hills, except in the Charnwood district, which stands at a higher level.

The oldest post-Glacial deposit is the high-level valley gravel flanking the Trent and Derwent Valleys on the northern side, and it forms a sort of passage from Glacial to Recent times. River terraces border all the main rivers at about a height of 15 to 20 feet above the alluvium, from which they usually rise in a sharp bank. They become mingled with modern alluvial deposits where tributary streams enter. *Hippopotamus*, *Elephas*, *Rhinoceros*, and *Bison* are recorded from them. For the most part, contemporaneous with the terraces are lacustrine deposits lying in hollows in the Keuper marl; Sinfin Moor is the best example. Alluvium covers a considerable area in this district owing to several important streams running into the Trent here. It is 20 to 30 feet thick.

The last chapter is devoted to a description of the faults, and is followed by an Appendix of 30 pages of Borings and Pit Sections. An Index concludes the work. There are a number of figures in the text and a fine plate of High Sharpley, Charnwood Forest.

REPORTS AND PROCEEDINGS.

I.—British Association for the Advancement of Science. Cape Town, South Africa, August 16th, 1905.

Address to the Geological Section (C) by Professor H. A. Miers, M.A., D.Sc., F.R.S., President of the Section.

IN opening the proceedings of Section C on its first visit to South Africa, and speaking first on behalf of those who are visitors, I think I may justly claim that to no Section of the British

Association can this visit be more interesting or even more exciting than to us; we enter for the first time a country whose geological features and history, and whose mineral productions, have long aroused the keenest interest among European geologists and mineralogists.

We have followed the discoveries and discussions of South African writers; we have read your views and have become familiar with your terminology; we have heard the reports of those who have visited the country, either as travellers or with the special object of investigating its geological problems or mineral resources; and, indeed, ever since the Geological Society of London received the historic papers of Andrew Geddes Bain, the father of South African geology, many of the memoirs of your own geologists have been communicated to European societies and journals; we have looked from afar with yearning eyes upon this alluring country; and at length we have found ourselves upon its shores.

It has not been given to many of us to see those great pioneers of South African geology whose work was done in the days before amateurs and experts could come out for a few weeks or months to take a hurried survey of the country; but their enduring labours, which have laid the foundation of all subsequent work, are well known to us, and it is not necessary for me to do more than mention the familiar names of Bain, Wyley, Stow, Atherstone, Sutherland, and Dunn. Of these only the last-named survives; but when one remembers that his maps of North Cape Colony and of Orange River Colony have served as the basis of the maps now in use, one is reminded how recent is the whole history of South African geology, and how much was achieved in so short a time by these early workers.

It is exactly one hundred years since John Barrow wrote the concluding words of his "Travels in South Africa" which first directed attention to the geology of this country; it is only fifty years since Bain sent home the manuscript of the classic papers to which I have already alluded.

Since their days many have been the scientific visitors to the country who have remained here for longer or shorter periods, whose works have made us familiar with its problems and have contributed to their solution; the names of Cohen, Draper, Exton, Gibson, Green, Griesbach, Passarge, Rubidge, Sawyer, Schenck, and Seeley recall some of the most substantial scientific work which has been done either by visitors or residents. Several others who, without visiting the country, have by their researches in Europe helped to unravel the problem of South African stratigraphy were enumerated by Dr. Corstorphine in his interesting and exhaustive Presidential Address last year.

If we must regret that we never had the opportunity of seeing the great pioneers and the earlier workers, we may rejoice that we have been able to meet those who are now actively engaged in continuing their labours; the period of cursory visits and fragmentary essays is closing, and the era of deliberate and systematic surveys is

beginning; we now look for authoritative information to the Cape Survey inaugurated by Dr. Corstorphine in 1895 and so ably continued by his successor Mr. Rogers; to the Transvaal Survey begun by Dr. Molengraaff in 1897 and auspiciously revived under Mr. Kynaston; and to the Natal Survey which Mr. Anderson has so successfully directed since 1901. I hope that it will not be long before there is no part of South Africa outside the direct supervision of a systematic and well-ordered survey.

There is perhaps some danger lest in a developing country, where the commercial possibilities are prominently before all eyes, the immense importance of such surveys should be overlooked, and lest it should be thought that what appears to be purely scientific research may be left to take care of itself until the mineral wealth of the country has been explored. I cannot enter too emphatic a protest against such a view; how closely the two interests are knit together must be apparent to anyone who reflects that the nature and sequence of the more northerly formations which have yielded coal, diamonds, gold, and metalliferous deposits can only be studied in the light of the more intelligible geology of Cape Colony and Natal. It is, moreover, immensely to the advantage of South Africa that you have intimately connected with the mining industry geologists of such training as Doctors Corstorphine, Molengraaff, and Hatch, who have all gained valuable experience upon geological surveys.

I may now, perhaps, cease to speak merely as a representative of the visitors and identify myself more closely with the Section as a whole; for the most gratifying feature of this meeting is that it is not merely a visit of strangers who are enjoying your hospitality, but that with Section C of the British Association is fused Section B of the South African Association, so that for the time being we are all colleagues; and even such vexed questions as the correlation of the rocks of the Transvaal or of Rhodesia with those of the Cape, or the origin of Banket, or of Blue Ground, or the extension of the Main Reef Series (perhaps it is no longer necessary to include the problem of the Dwyka conglomerate) can be discussed by us on the spot as members of the same body inspired by the same earnest desire for truth.

I began these preliminary remarks by asking that I might be regarded as the spokesman of the visitors, and therefore represented myself as a geologist visiting the country for the first time. I must, however, make a frank confession. Not only is this my second visit to the country, but I have not even any claim to be called a geologist. My training and experience have been such that upon many of the questions which must be most interesting to this Section I am not competent to form an opinion or to appreciate properly the evidence. I must, therefore, crave your indulgence if in this Address I refrain from discussing any of the problems of surpassing interest which naturally engage the attention of those who are occupied with the study of South African geology. It would indeed be an impertinence for me to do so.

I venture, however, to hope that the frontier between geology and mineralogy is so ill-defined—if indeed a scientific frontier can be said to exist—that the thoughts and occupations of one who has confined himself to the study of minerals, and that rather in the laboratory than in the field, are not alien to the interests of Section C.

Experimental Geology.

A somewhat lamentable aspect of modern science is the vast array of unorganised facts which are awaiting co-ordination; this is too often because they have been amassed without any definite idea of the purpose which they may serve; consequently it may happen that laborious observations belonging to one science may fail to attract the regard of a neighbouring science merely for want of the mutual acquaintance which would make them serviceable to each other; and in these days of exclusive specialisation the introduction which might lead to a happy union is, perhaps, not brought about for years. None can be more fully alive to the importance of such an alliance than those whose work lies on the borderland between different sciences; the mineralogist, for example, is in contact on the one side with the experimental sciences of chemistry and physics, and on the other with geology, which has scarcely yet entered the experimental stage. He cannot fail to be impressed by the need of the appeal to experiment on the geological side of the border, and it is perhaps his duty to supply the want as far as lies in his power.

Owing to this very need some of the most difficult problems in geology are those concerned with the origin of minerals and of the rocks which they compose. One need but recall the many theories which have been held about the origin of mineral deposits, the filling of metalliferous veins, the local concentration of certain minerals, the distribution of various rock types, the existence of rock magmas of diverse compositions, and the differentiation of their constituents. Could the importance and difficulty of such problems be better illustrated than in South Africa, and by its two most valuable minerals, gold and diamond?

Now all these are problems in which direct appeal may, and indeed must, be made to laboratory experiments; the well-defined minerals of which the earth's crust consists do not, after all, number much more than 800, and of these many have already been manufactured in the laboratory. Speculation upon the origin of rocks and minerals should surely be controlled by the results of experiments, and equally should experiment which is to be of service to geology be guided by a knowledge of the problems to which it is to be applied. It will be my object in the present Address to illustrate these principles by examples drawn from recent experimental work which can be applied to geological problems, and to indicate the course which such research is likely to pursue in the immediate future.

It seems to be sometimes expected of a Presidential Address that it should contain a summary of the progress of a science during past

years, and this is no doubt very useful and instructive; but if we are to go forward in our scientific work we must not be satisfied with the patient accumulation of details, or content to congratulate ourselves upon the number of them which have been amassed. I venture to think that it is more profitable to take our stand upon the actual work of to-day, and from that tower of observation to look forward to the future rather than backwards to the past; to exclaim with the poet—

> "No, at noonday in the bustle of man's work-time
> Greet the unseen with a cheer!
> Bid him forward."

It would be interesting enough to trace the history of the artificial reproduction of minerals, beginning with the famous experiment of James Hall; to follow the lines that led to the development of the French School during the last half of the nineteenth century; to dwell on the researches of Senarmont, Ebelmen, Daubrée, and Sainte-Claire Deville; to show how the increasing study of petrography and the invention of the electric furnace have led to renewed activity in the attempts to reproduce igneous rocks and the rock-forming minerals; to discuss the more modern experiments of Fouqué and Lévy, Lagorio, Loevinson-Lessing, and Morozewicz; or to describe the manufacture of many an interesting mineral by de Schulten and others who are actively prosecuting research of this nature, including such sensational achievements as the production of the ruby by Frémy and of the diamond by Moissan.

Instead, however, of attempting a survey of all that has been done, or even of all that is being done in the artificial reproduction of minerals, let me adhere to the principle that I have laid down, and discuss only a few of those researches, now being carried on, which promise to be most fruitful because their methods and aims are inspired by the discoveries and views of modern chemistry and modern physics.

Van 't Hoff's Work on the Salt Deposits.

Among such researches the most remarkable are those conducted by Professor van 't Hoff and his pupils during the last eight years upon the Stassfurt salt deposits. These deposits are of enormous extent, more than 1,000 feet thick, and consist of fairly well-defined layers of various sulphates and chlorides of sodium, magnesium, and potassium, and their double salts and hydrates. It has long been supposed that the minerals have been derived from the evaporation of sea-water which contains in solution the chlorides of sodium, magnesium, and potassium, with sulphate of magnesium and small quantities of calcium salts; and the general sequence of the minerals is that of their solubility; the less soluble sodium chloride crystallised out first and is at the bottom, while the very soluble magnesium chlorides, having been the last to crystallise, occupy the top of the series. But the problem is by no means so simple as to be one of mere solubility in water; the rock salt itself persists through the whole series, and some of the associations are difficult to explain.

As is well known, the modern theories of solution mainly rest upon the behaviour of dilute solutions from which the principles of electrolytic dissociation have been deduced; but in the case of the concentrated solutions from which dissolved substances actually crystallise, very little is really known about the liquid itself. A great deal is known, however, about its equilibrium with the solids that separate from it, and the general laws of this equilibrium are expressed by the phase-rule deduced from mathematical considerations by Willard Gibbs, which states how many mechanically separable constituents can coexist under varying conditions of equilibrium in a system containing a definite number of chemical components.

A solution saturated with a given substance is one which is in equilibrium with that substance when the latter is in contact with it in the solid form; the phase-rule indicates the number of solids which must be in contact with a given solution; the only difficulty in practice is to determine the nature of the double salts or distinct hydrates that may be formed.

By means of a series of experiments upon the solubilities of these salts, either singly or in the presence of one another, in order to determine the composition of solutions saturated simultaneously with two or more substances, it is possible to obtain a graphic representation of all possible solutions containing the salts present in sea-water. From this the course of crystallisation of any particular solution, for example sea-water, can be predicted.

The general sequence thus theoretically predicted is as follows:—(1) Rock salt; (2) Rock salt with the magnesium sulphate, epsomite; (3) Rock salt with the double sulphate of potassium and magnesium, leonite; (4) Rock salt with leonite and the potassium chloride, kainite; (5) Rock salt, the magnesium sulphate kieserite, and the double chloride of potassium and magnesium, carnallite; (6) Rock salt, kieserite, carnallite, and the magnesium chloride, bischoffite. This last combination will persist until all the water is evaporated. This is found to be the general sequence, not only of the salts obtained on evaporating sea-water at 25°, but also of the Stassfurt deposits.

Up to this point the results have been summarised by Dr. E. F. Armstrong in a report presented to the British Association in 1901. Since that date the research has been prosecuted actively by van 't Hoff and his pupils, and now the conditions of equilibrium at 25° have been mapped out, not only for the above compounds, but also for the minerals thenardite, glaserite, astrakanite, and reichardtite, which occur in these deposits. The whole process of crystallisation of the solution, from which no fewer than twelve different salts have separated, can, therefore, be predicted, and their sequence and associations can be traced through numerous stages, beginning with the separation of rock salt and ending with a mixture of rock salt, kieserite, carnallite, and bischoffite.

In reconstructing the history of these deposits account must also be taken of the varying vapour pressures of the solutions which are saturated with the different compounds, as this really determines

which particular compounds are stable, so that the matter is by no means so simple as might appear from this brief sketch. It is further necessary, in order to bring the process within reach of calculation, to assume that each deposit is removed from contact with the mother liquor after it has crystallised out; but fortunately this is practically what has happened in the Stassfurt deposits, for each layer is more or less separated from the succeeding one by an intervening layer of clayey material.

It may be possible even to go a stage further and obtain a clue to the actual temperatures that prevailed, for two minerals, langbeinite and löweite, are absent from the theoretical model made by van 't Hoff to represent what must happen during evaporation at 25°; and this indicates that while the deposits crystallised the temperature really rose higher than 25°, probably as high as 43°; in fact, after the conditions of equilibrium have been worked out, the appearance or disappearance of certain minerals can be used as a sort of geological thermometer, capable of indicating the limits within which the temperature can have varied.

The whole investigation is a splendid example of experimental research devoted to a particular problem and directed by a well-established theory; the chemist in his laboratory has now succeeded in tracing the changes that took place ages ago in the bed of a land-locked sea as it laid down its contents and finally became a dry basin, although he is not able to reproduce the original conditions or to work for the long periods which Nature had at her disposal. Without the logical consideration of the conditions necessary for equilibrium, countless experiments might be made upon these salts, and an immense amount of speculation might have been devoted to their possible reactions in the liquid state, about which we know so little, instead of to their equilibrium when solidifying, about which we know so much more.

Some Petrographical Problems.

The other geological problems which I have mentioned have also been beyond the reach of actual experiment, for it is hopeless to attain the immense pressures and high temperatures or the enormous time that may have been required for the growth of natural minerals in rocks and veins; and so when difficulties are encountered there is a tendency to 'explain' them (if the word may be so misused) by reference to the mysterious effect of conditions which cannot be brought directly within the reach of experiment.

I cannot help thinking that this has to some extent occurred in the discussion of the petrographical problems which I propose to consider next. There are two great liquid reservoirs from which minerals have crystallised—the sea, with its dissolved salts, and the subterranean baths of molten silicates, from which the igneous rocks have been derived. It is true that in the sea two of the constituents, water and sodium chloride, largely predominated over the others; but, after all, both sea and lava are liquids subject to the same physical and chemical laws.

An admirable summary of the evolution of petrographical ideas was given in the Presidential Address to the Geological Society of London in 1901 by Dr. Teall, who dealt both with the consolidation of rocks from molten magmas and their differentiation into species. It is not, therefore, necessary for me to consider anything but recent work which has been done during the last four years, and the earlier controversies may be left out of account.

Among the many problems relating to the mineral and chemical constitution of rocks which have yet to be solved, two, and those perhaps the most important, should lend themselves most readily to experimental treatment. The first is the problem of rock differentiation: why does a magma, even one which has presumably crystallised *in situ*, separate itself into zones, or layers, or streaks of different constitution? And the second is the problem of mineral differentiation: why does a granite magma, for example, crystallise as a mixture of the particular minerals mica, felspar, and quartz, and why is the least fusible mineral the last to crystallise?

It will scarcely be possible for me to deal in this Address with more than the second of the two problems, but it will be apparent from the somewhat parallel case of the salt deposits that the mere order and manner of crystallisation of a mass of molten silicates must be a sufficiently complex problem to exhaust our attention for the present.

Magmatic Differentiation.

If we are to consider only recent experiments which have a bearing upon the problems of rock-magmas, it is not necessary to say much about the first great petrographical problem, that of the differentiation of magmas into various rock types; for in this connection very few experiments have been made, and practically none of recent date. Observations of the facts as they present themselves in the field accumulate every day; almost every important petrographical region is being studied with the particular object of determining the mutual relations of its rock-masses and the factors which have contributed to their differentiation. They have been ably discussed by Becke, Brögger, Becker, Cole, Harker, Iddings, Judd, Lacroix, Lévy, Pirsson, Rosenbusch, Teall, Washington, Zirkel, and many others; appeal has been made to the action of gravity, of temperature differences, of diffusion, of electric currents, of fractional crystallisation, of refusion, of chemically combined water, of absorption of the country rock; but with the exception of a single case, observed in the glassworks of Targowek, in which the top of a molten glass was found to contain less lime and more silica than the bottom, and some observations by Doelter upon boron-glass, there is scarcely a single experiment upon silicates which really bears directly on the question. That artificial glasses are far from homogeneous is known to glass-workers and to makers of lenses, but there is nothing comparable with the splitting of a magma into two or three distinct liquids which solidify as different rocks.

It is in the case of laccolites that the problem ought to present itself in the simplest form, for we may regard them as basins of

igneous rock which have been practically imprisoned within solid walls and have crystallised *in situ*. There can, I think, be no doubt that differentiation has generally taken place even in such basins, that the margins have often a different mineralogical and chemical constitution from the more central portion, and that the differences are greater than can be accounted for by solution of the enclosing rock, and are often of a chemical nature which cannot be so explained.

The various theories that have been propounded fall into two distinct classes—those which seek the cause in the separation of solid material from the liquid, so that when the latter subsequently crystallised it constituted a different rock from the former; and those theories which assume that different liquids have separated from each other and then solidified as different rocks.

The first conception satisfactorily explains the manner in which the least soluble minerals are concentrated at the bottom or margin of an igneous mass, for they naturally crystallise first where the mass is coolest, or where contact with other crystals may have occurred; or even if they have been precipitated as a cloud throughout the magma they must be carried about by convection currents and ultimately sink together unless the magma be very viscous. Most geologists will probably agree with the conclusions of Vogt that some of the most important deposits of metal, metallic oxides, and sulphides have been produced by magmatic differentiation from deep-seated magmas which now constitute basic rocks associated with them. But this does not explain how the mass which has crystallised out may be not a mineral but a rock.

The actual observations on crystallising solutions do not amount to much; it is quite clear from laboratory experiments that crystals do grow by means of convection currents, which produce a flow of stronger solution towards the crystal and of weaker and warmer solution upwards and away from the crystal. The concentration currents can easily be seen in any ordinary aqueous solution as streaks in the liquid. Again, that there might be a slight difference in the concentration of the upper and lower, or of the warmer and cooler parts of a solution has also been shown. That a very considerable difference in concentration can be produced by centrifugal action was proved only last year by the experiments of Calcar and de Bruyn, in which solutions contained in rapidly rotating vessels became more concentrated in the portions furthest from the axis of rotation.

Schweig has recently suggested that the crystals which fall to the bottom of a rock-magma may be unstable compounds, which redissolve when the pressure is relieved, and so give rise to an underlying magma of different chemical constitution.

Harker, also, some time ago, suggested the existence of horizontal layers of different liquid magmas above each other, thus attempting to explain the presence of quartz in basic rocks as due to the crystals which had sunk into the basic magma from a more acid magma floating upon it.

The second theory, that of liquid differentiation, regards such layers as actually produced by the spontaneous division of a magma into two liquids of different composition, and if it be tenable seems more capable of explaining the geological facts.

The experiments bearing on the subject are well known, and have been quoted by Bäckstrom and Teall; mixtures of phenol and water, or of aniline and water, which form a homogeneous solution above a certain temperature, may below that temperature (which is a sort of critical point of the solution) divide into two solutions, one consisting of phenol in excess of water, the other of water in excess of phenol; and these two solutions are not miscible, but separate into two distinct layers.

Many pairs of substances have now been found to exhibit this incomplete miscibility, which varies with the temperature and may at certain temperatures become complete; among them are some of the metals such as zinc, lead, bismuth, and silver.

If rock-magmas can really behave in this way, there is no difficulty in explaining their differentiation; but experiments upon fused silicates have not disclosed anything of the sort, though they are made far below the critical temperature.

The case of nicotine and water, which has recently been described by Hudson, is remarkable and suggestive: above a temperature of 205° a mixture in equal proportions is a clear liquid; at 205° it divides into a saturated solution of nicotine in water floating on a saturated solution of water in nicotine; at 90° these two layers change places; at 64° they mix again and the liquid becomes once more homogeneous.

It is, of course, possible that fused silicates at experimental temperatures correspond to nicotine and water below 64°, and that rock-magmas correspond to the same mixture at higher temperatures.

In discussing the reasons why in laccolites of the Square Butte type the margin should be more basic, and in laccolites of the Magnet Cove type more acid than the centre, Washington regards the magma as a mutual solution of an alumo-alkaline substance with a ferro-magnesian substance; whichever of these is in excess may be regarded as solvent, and crystallises first, for example, either the syenite or the shonkinite. In a laccolite where no differentiation has taken place, as in the Henry Mountains type, he supposes the mixture to be eutectic or such that they crystallise together. Pirsson, in a paper recently published upon the "Highwood Mountain Laccolites of Montana," while attributing a greater part in the process to the action of convection currents, also regards the ferro-magnesian minerals, taken together, as constituting the solvent and crystallising first as shonkinite.

In fact, stated quite baldly, these latest views tend to a compromise between the two theories which I have just mentioned. They regard the splitting of the magma as produced by a fractional crystallisation, only now the mass which crystallises is not a mineral but a rock; in other words, they assume that rocks may be dissolved in each other, and may crystallise from each other as though they were minerals.

In this matter of magmatic differentiation, then, there has been during the last few years a large accumulation of geological evidence, a little new speculation, but practically no new experimental work, and scarcely any progress.

Mineral Differentiation and Eutectics.

Let us pass to the second petrographical problem, that of mineral differentiation, the nature and order of the minerals which crystallise when a cooling magma becomes a solid rock-mass.

It has been laid down by Rosenbusch, and is accepted as a general rule (in spite of many exceptions), that the order in which the various minerals crystallise is one of increasing acidity, ores and oxides and so-called accessory minerals first, then those minerals which are comparatively poor in silica, then those which are richer, and finally, if it be present in excess, the silica itself. It has also been supposed that the order may be one of the fusibility of the various minerals under the conditions of their formation; the least fusible minerals being the earliest to crystallise, and the most fusible the latest. Interesting speculations concerning the melting-point of quartz at high pressures, and its consequent order of crystallisation, have, for example, been published recently by Stromeyer and Cunningham.

It is not necessary, however, to regard the molten magma as a mere mixture of fused minerals which solidify more or less independently and consecutively; it is more reasonable to regard the whole magma as a solution in which the various minerals are dissolved, and from which they crystallise as it cools. Now the temperature at which a substance separates from solution is generally far below its melting-point, and the order in which the constituents of a mixed solution will crystallise is the order of their solubility in it, and bears no direct relation to their fusibility or to their chemical composition.

Teall in 1901, after discussing the controversies and the evidence on which they are based, came to the conclusion that rock-magmas are solutions, and that the order in which the minerals consolidate depends upon the nature of the constituents and their properties, and is not by any means the order of their freezing-points. As to the particular minerals which crystallise, he thought that the molecular grouping in the magma is determined by mass action and by the mutual affinities of the bases, the silica, and the alumina. Concerning future research he ventured to predict that the next advances were to be made by experiment controlled by the modern theory of solutions.

Thirteen years earlier Teall had himself contributed a valuable suggestion based upon Guthrie's work on cryo-hydrates. When a mixture of nitrate of lead and nitre is fused and allowed to cool, the constituent which is in excess will crystallise out as from a solvent until the proportions left in the liquid state are 47 of lead-nitrate to 53 of nitre, and this mixture will then solidify at 207°, not as a uniform compound, but as an intimate mixture of the two

salts, the *eutectic*, which crystallises at the lowest possible temperature, and is the only mixture which has exactly the same composition as the liquid from which it solidifies. Teall made the illuminating suggestion that micropegmatite is an eutectic consisting of quartz and felspar, and represents in certain rocks the final mother liquor from which the other minerals have crystallised out. Eutectics in metallic alloys have been much studied during recent years; in the Address of 1901 Teall was able to strengthen his case by showing that spherulitic and micropegmatitic structures found in obsidian and other acid rocks are paralleled by similar structures developed in eutectic alloys, according as they have been rapidly or slowly cooled.

In the following year appeared a theoretical paper by Meyerhoffer concerning the ideal case of a molten mixture of two substances, *a* and *b*, which do not suffer double decomposition, nor form a double salt, nor an isomorphous mixture.

Let a diagram be constructed, with temperatures as ordinates and composition of the magma as abscissæ, giving by a curve the nature of the magma which is in equilibrium with either solid *a* or solid *b*. The curve has the form of a V; one arm represents the temperature and constitution of the liquid which can be in equilibrium with *a*, and the other that of the liquid which can be in equilibrium with *b*; and the lowest point corresponds to the eutectic, which is in contact with both.

Let a point above the curve represent the temperature and constitution of the liquid magma containing excess of *b*; as the magma cools this point descends to the *b* branch and travels along it while *b* is crystallising out, until the eutectic point is reached, when *a* and *b* both crystallise out together at a temperature below the melting-point of either. The order of crystallisation is therefore determined solely by the composition of the magma as compared with that of the eutectic. If, however, the liquid be cooled slowly, crystallisation may be postponed until it has become supersaturated with regard to one constituent or the other, or both; a state of affairs represented by a prolongation of the arms of the V below its lowest point, and then the order of the crystallisation may be inverted.

In a rock-magma there are of course many other factors to be taken into account as determining the order in which the minerals separate; for example, the formation of both double salts and isomorphous mixtures, the possible production of unstable solid compounds which may become converted into stable compounds or may be redissolved soon after they have come into existence; and also the relative velocities of crystallisation, changes of temperature and pressure, action of steam, etc.; but the principle laid down by Meyerhoffer must be that which controls the process.

It might be objected that on this hypothesis the consolidation of every rock-mass ought to terminate with an eutectic mixture, whereas this appears to be by no means the case; in fact, it is only among some acid rocks that structures much resembling the eutectic mixtures of alloys are to be found. On the other hand, if the

conditions of cooling are such that the magma becomes supersaturated with one mineral after another, it will overshoot the eutectic composition before each crystallises, and the final consolidation may be a well-marked sequence instead of a simultaneous crystallisation.

The controversies which have raged concerning the classification of rocks and their nomenclature appear to me to contribute little to the real advancement of knowledge. There are, I think, two more profitable lines of research which should accompany each other. We may take the facts as we find them, and endeavour to explain them by the known laws of solutions aided by the phase-rule, provided that we have good reason to believe that rock-magmas behave like solutions, and we may make experiments upon slags and fused silicates and ascertain how far they resemble natural rocks in their behaviour and their mineral constitution. Some of the workers in this field have been led to regard rock-magmas as undoubtedly similar to ordinary solutions; others hesitate to seek an explanation for their features in the laws which govern the solutions studied in the laboratory. The two views are represented in the persons of the two men whose names are most closely identified with recent experiments, Vogt of Christiania and Doelter of Graz.

(*To be continued.*)

II.—Mineralogical Society of London.

Mineralogical Society, June 14th, 1905. Professor H. A. Miers, F.R.S., President, in the chair.—The Chemical Composition of Lengenbachite, by Mr. A. Hutchinson. A quantitative analysis of the new mineral from the Binnenthal, recently described by R. H. Solly, leads to the formula $7\,PbS,\ 2\,As_2S_3$, part of the lead being replaced by silver and copper and part of the arsenic by antimony.—The Chemical Composition of Hutchinsonite, by Mr. G. T. Prior. Chemical examination of this new and extremely rare mineral from the Binnenthal, described by R. H. Solly, showed that it could be added to crookesite and lorandite as a third mineral containing the rare element thallium as an important constituent. Quantitative analysis, made on a small amount of material (about 70 mgr.), showed the presence of about 20 per cent. of thallium and suggested the formula $(Tl, Cu, Ag)_2\,S\,As_2S_3 + Pb\,S\,As_2S_3$.—The identity of the Amiantos of the Ancients with Chrysotile, by Dr. J. W. Evans. The principal source of amiantos appears to have been Cyprus. Specimens brought by Prof. Wyndham Dunstan from the ancient workings on the slopes of Mount Troodos prove to be chrysotile and not tremolite asbestos. A chemical analysis by G. S. Blake confirmed this result.—Gnomonic Projection on two Planes at Right Angles, by Dr. J. W. Evans. By means of these projections and the rotation of one plane on an axis at right angles to the other, simple solutions of crystallographic problems are obtained.—The President exhibited supersaturated solutions of sodium nitrate, showing the transition from the metastable condition, in which crystallisation is only possible in the presence of solid crystals, to the labile condition, in which the liquid can crystallise spontaneously.

III.—Palæontographical Society.

The fifty-eighth annual general meeting of the Palæontographical Society was held at the Geological Society's apartments, Burlington House, on Friday, 16th June, Dr. Henry Woodward, F.R.S., President, in the chair. The annual report of the Council and the balance-sheet were submitted for the approval of the members, and they were adopted on the proposition of Sir Archibald Geikie, Sec. R.S. The report congratulated the Society on its continued prosperity, and alluded to the activity of its members in the promotion of research. The Council were still embarrassed by more offers of memoirs than they could accept for immediate publication, and they had again spent a large sum beyond their income on the volume for 1904. This volume contained an unusual amount of letterpress with expensive tables, and was devoted to continuations of the Monographs of Old Red Sandstone Fishes, Inferior Oolite Ammonites, Carboniferous and Cretaceous Lamellibranchs, Girvan Trilobites, and British Graptolites. The Council had carefully considered the financial position of the Society, and had decided to issue a comparatively small volume for the year 1905. They proposed in future to end the financial year on 31st December instead of 31st March, so that the year should correspond exactly with the period to which the annual guinea related. They also proposed that in future the price of the annual volume to non-subscribers should be twenty-five shillings net. Dr. Henry Woodward was re-elected President, and Mr. E. T. Newton a new Vice-President; Dr. G. J. Hinde and Dr. A. S. Woodward were re-elected Treasurer and Secretary respectively. Professor W. J. Sollas, Mr. F. W. Harmer, and Mr. P. Lake were elected new members of Council.

CORRESPONDENCE.

THE CORRELATION OF THE BOVEY LIGNITE BEDS.

Sir,—In the periodical discussions that take place on the Bovey Lignite Beds, it seems always taken for granted that the late William Pengelly believed them to be of Miocene age, and not connected with any other known British beds. In 1865 Pengelly published his paper "On the Correlation of the Lignite Formation of Bovey Tracey, Devonshire, with the Hempstead Beds of the Isle of Wight" (Trans. Dev. Assoc., vol. i. pt. 4, p. 90), and observed that "they are all Lower Miocene or all Upper Eocene; for they must certainly go together." He tells us that Mr. Keeping, who made the excavations at Bovey, collected for him plant-remains at Hempstead, and that, of ten species secured, four occurred at Bovey, two were new to science, and two were new to Hempstead. One of the Hempstead and Bovey plants was *Sequoia Couttsiæ*.

It will be seen that thirty years ago Pengelly linked the Bovey and Hempstead Beds together as what are now known as Oligocene; but Mr. Starkie Gardner has since then for weighty reasons referred

the Bovey Beds to the Bournemouth horizon as Eocene. My reason in writing on the subject is that Pengelly's Hempstead flora seems to have been overlooked. Indeed, in a recent text-book I cannot find either Hempstead or its beds, unless Hempstead has turned into Hamstead.[1] As the collection seems to have been specially made for Mr. Pengelly, and he recorded it in a paper of four pages in provincial transactions, its burial may have been too effective.

With regard to sands suspected to be of Dartmoor origin, the question can be readily settled by the character of the inclusions in the quartz. With respect to the Bovey clays, the presence of the kaolin at Bovey is exactly matched by its absence from its place on Dartmoor, where there is much evidence of the dissolution and removal of the felspar. This might be looked for with a semi-tropical vegetation and much consequent carbonic acid.

Referring to the Rev. Osmund Fisher's interesting note about the pink felspar crystals, which he suggests may have been derived from the English Channel area, he might be interested to examine the collection of rocks from the English Channel which were graciously accepted by the Woodwardian Professor, now many years ago. There was no evidence in the Channel of rocks likely to decompose and liberate pink felspar crystals. No. 2, with "large pale flesh-coloured orthoclase twins," is a hard rock. There is an abundance of red felspars on Dartmoor, ranging from a dark brick red; but these run in shades of red rather than pink, and are, so far as I am aware, not orthoclase. Moreover, if associated with quartz, they could be authoritatively distinguished from the Channel felspars, so far as those are known.

I feel an apology is due for my thus trespassing on your space on a subject which, except indirectly, is foreign to my own lines of inquiry. Of the Eocene and Miocene floras I am profoundly ignorant, but the discrimination of sands derived from the Channel and from Dartmoor is a simple matter in many cases. If sands contain chlorides we may be sure they were not derived from rocks known in the Channel; whereas if chlorides are entirely absent we may be equally sure they do not hail from Dartmoor.

The problem of the flora is as follows:—According to Pengelly and Keeping the Bovey Beds are equal to the Hempstead Beds, and are Tongrian. According to Mr. Starkie Gardner the Bovey Beds are equal to the Bournemouth Beds, and are Lutetian. Hence, according to Euclid, Tongrian must be equal to Lutetian, or Oligocene = Eocene, "which is absurd." The most obvious solution is that Euclid is a discredited text-book, and that things which are equal to the same things are not equal to one another. A plausible explanation would, however, assume that Pengelly misnamed his Hempstead fossil plants; but it is clear they were described by some expert specialist, as new species were detected. A. R. Hunt.

July 11th, 1905.

[1] [The original name for the locality in the Isle of Wight is Hamstead, which was changed by the Survey into Hempstead.—Edit. Geol. Mag.]